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THE HUMAN FACTOR IN SCIENTIFIC RESEARCH

NO one could claim that the Conference on Scientific Research and Industrial Planning held by the Division for the Social and International Relations of Science of the British Association (see p. 8) in London on December 7 and 8 broke fresh ground or threw up any new ideas. One of its most interesting features was rather the evidence it afforded of the way in which ideas once regarded as impractical or revolutionary are permeating the whole field of science and industry, and indeed of Government itself. Already it is clear that principles advocated in the Barlow Report on scientific staff, in the Nuffield College Statement on Problems of Scientific and Industrial Research and in reports from the Parliamentary and Scientific Committee, the Association of Scientific Workers and the Federation of British Industries, to mention only a few, have found widespread acceptance. Speaker after speaker, whether from the industrial, the academic or the Government side, referred to the importance of such factors as the interchange and mobility of staff, freedom in the publication of results, the importance of status and the like in attracting the right type of mind and in encouraging creative and original thinking. The lessons of team-work demonstrated so convincingly during the War are being taken to heart, and it is realized that such co-operation and team-work must above all be based on conditions of employment which both attract the right type of man in sufficient numbers and stimulate him to give of his best.

It might well be argued that the title of the Conference was something of a misnomer, and should have been "The Human Factor in Scientific Research"; for the human factor, not the subject of research, except in so far as that itself embraced the human factor, was the main theme of the Conference. One session was indeed devoted essentially to the human factor as a field of research; but although two of the papers at the opening session were concerned with research on specific technical subjects, in essence they were concerned to make the point that, without sufficient freedom in academic research, neither the fundamental knowledge nor the qualified investigators would have been available for dealing with the urgent problems that arose in certain fields during the War. Taken as a whole, the Conference displayed a remarkable agreement on tactics; though equally it left no room for doubt as to the need for applying such tactics much more widely and vigorously throughout Government departments, industry and in the universities in order that the supply of trained research workers may be adequate for the country's needs both in quality and in numbers, and that the most effective use may be made of their abilities.

The application of tactics can scarcely be dissociated from some measure of planning, in science any more than in other fields; but one of the most striking features of the Conference was the *rapprochement* between the more vigorous protagonists of planning and the defenders of the freedom of science

Prof. Polanyi's fine address at the opening session struck a note which was generally welcomed, and the fundamental importance of freedom of investigation and of communication was emphasized from all quarters; so much so that the staccato enumeration by Prof. J. W. Baker, at the end of the second session, of discoveries which could not have been planned struck a jarring note. From the point of view that whatever planning in fundamental research might be necessary as a matter of priorities should be in the hands of scientific men themselves there was no dissent; and the opening sessions of the Conference once more stressed that in regard to fundamental research the right policy is to see that it is adequately endowed and allowed to develop along the lines which the search for new knowledge alone directs, leaving the investigator the widest possible freedom in selecting his subject.

Although the importance of freedom of investigation and communication was fully recognized, and also the desirability of allowing fundamental research to develop along its own lines, it was equally recognized that some measure of direction is necessary to secure the full use of Great Britain's resources of man-power and materials. Even when conditions are such as to attract into a scientific career a sufficient proportion of the ablest minds, we have to remember that our scientific man-power is not unlimited. At the moment, the bottleneck in the way of expansion, as Mr. J. A. Lauwerys pointed out, is in teaching, and as has been suggested by Sir John Anderson (see *Nature*, Dec. 22, p. 733) industry may have to forgo its demands while university departments are equipping themselves to train the increased number of research workers and other scientific workers required by industry, government departments and the universities themselves. Equally, however, it would be undesirable at another period for an excessive proportion of the ablest men to enter industry or government departments, leaving the universities starved of the best brains for teaching or research, and as has already been said, some measure of wise planning is indispensable to secure the application of the correct tactics at the right time.

Apart from this, the Conference also emphasized that not only has the management of research to pay attention to the recruitment, training and handling of the research worker, so as to secure the right quality and the fullest use of the comparatively limited numbers available, but also that the human factor, and indeed the whole social and economic aspects of production, offer a field in which the application of scientific methods is required on a much larger scale, especially in Britain. The two aspects are in fact closely linked, for as was pointed out in a reference to the success of team-work in our war effort in enlisting individuality and originality of thought in the attack on definite objectives, a large part of research management lies not merely in the selection of objectives and programmes of work but also in securing a proper balance between the different elements in the team, and in so handling the personalities and aspirations of its members as to provide an environment favourable for creative effort. The operational research to which passing reference was made at the Conference is clearly a field worthy of close study, both by scientific workers in general and the industrial psychologist in particular, and a careful examination of the reasons for its outstanding success may yield invaluable lessons to be applied in facing the post-war problems.

Prominent among the problems which, in addition to those enumerated by Mr. Alec Rodger, require the attention of the industrial psychologist is that of incentives. The importance of the social motive as a stimulus to research had been stressed at the earlier conference on "The Place of Science in Industry" held under the auspices of the British Association a year ago, and Mr. Herbert Morrison referred to the importance of social purpose as an incentive to match the inspiration derived from the nation's needs in war. Sir Edward Appleton referred significantly to the way in which such an incentive influences young scientific workers who consult him regarding the choice of a career. Mr. Rodger incidentally expressed the view that industrial psychology will only be able to make its full contribution to social and economic life when a full employment policy has been implemented and we have a planned wage structure for the whole of industry, so that the workers are no longer anxious as to whether improvements would result in fewer jobs for fewer people.

Although nowhere consciously expressed, the Conference was pervaded by the sense that these themes —the freedom of science, its value as a cultural activity, the wide application of the scientific outlook and method to problems of economics and management, the study of the human factor and the question of incentives and the structure of society—are not unrelated, but represent threads which must be woven into a coherent pattern if scientific research is to make its full contribution to human welfare at the material, the administrative or the cultural level. The fundamental need is for a closer and fuller integration of academic and industrial research, of industry and Government, with the needs and purposes of the society they exist to serve. To achieve this end, we require what Dr. J. T. MacCurdy suggested in "The Structure of Morale"—an intelligence or liaison system corresponding in efficiency and intricacy with that of the individual human brain.

The evolution of any such system is ultimately a problem in thinking. Much that was said at the Conference supported this comment of Dr. MacCurdy's on the problem of organisation, whether we look, internally, at the problems of the management and organisation of research or, externally, at those questions of public relations which so powerfully influence the application of the results of scientific and industrial research or the extension of its technique into the economic and social field. No one present at the Conference could fail to be aware of the difficulties in this task: the uneasiness and concern with which the new problems of the use and control of atomic energy are regarded was apparent at most sessions. The Conference represents a great challenge to thought, particularly on the part of the scientific worker himself. Colonel Urwick, who emphasized that challenge most clearly, saw too the

real reason for optimism, and the note of optimism with which he closed the session on "Economic Aspects of Research" is one on which the whole Conference might fittingly have closed. The obstacles are essentially human obstacles, and by right thinking they can be overcome.

THE COMPLETE CORRESPONDENCE OF LEEUWENHOEK

Alle de brieven van Antoni van Leeuwenhoek (The Collected Letters of Antoni van Leeuwenhoek). Uitgegeven, geïllustreerd en van aanteekeningen voorzien door een Commissie van Nederlandsche geleerden (Edited, illustrated and annotated by a Committee of Dutch scientists). Deel (Volume) 2. Pp. 506+29 plates. (Amsterdam: N. V. Swets and Zeitlinger, 1941.)

THE first volume of this great undertaking was published in 1939 and was reviewed in *Nature* of that year[1]. The edition is lavishly produced, the format being an 'off'-size octavo 11½ in. × 8½ in., beautifully printed on a good heavy paper, and suitably bound. The spacing of the text is unnecessarily generous, and clearly suggests a time when economy in paper and labour could be disregarded. Although the present volume was printed before the War, it was not published until 1941, and so far only two copies have reached Britain. Assuming that the enterprise is not compelled to sacrifice the completeness of the first two volumes, the letters will require another ten volumes of five hundred pages each, and a final volume of biography, critical essays and bibliography will bring the total to thirteen. The Commission, however, has estimated for twenty volumes, which, if correct, will dangerously postpone the completion of the work, and interest in a long-drawn-out publication is apt to waver and expire before the end of the task has been reached.

In our first review, occasion was taken strongly to criticize the hybrid character of the English translation of the letters. This might have seemed ungracious to many, especially as the knowledge of English of our Dutch colleagues puts to shame our own ignorance of Dutch. Nevertheless, good linguists as they are, the English version of Leeuwenhoek's letters reads strangely to a modern Englishman, and it is hence essential that the translation should be revised by an English biologist. This would not be a heavy task, since the Dutch translators may be trusted to render correctly the sense of the originals, and all that is necessary is to check transgressions against English idiom and literary form. We are glad to learn from Prof. G. van Rijnberk's preface that the Commission admits the justice of our criticism, and that future volumes will be free from the blemishes to which we were constrained to direct attention. Unfortunately, volume 2 was in type before the change could be introduced, and hence it perpetrates the same defects as volume 1, to which it would now be superfluous to direct attention. We may also expect further improvements from the fact that Dr. A. Schierbeek, of The Hague, has taken over the editorship of the work, and in the hands of this active biologist and Leeuwenhoek enthusiast the many problems of interpretation which Leeuwenhoek's unmethodical writings have bequeathed to his successors will be explored so far as is humanly possible. Holland itself can supply the learned advisers whom he will need. We may take this opportunity to express our deep sympathy with Dr. Schierbeek, whose house and valuable library were bombed and destroyed during the War. But his soul goes marching on.

The present volume includes letters 22–42 (new enumeration), but the manuscripts of letters 24, 29 and 36 have not been recovered, and hence only eighteen letters are dealt with in a volume of more than five hundred pages. The list, however, includes the long letter 18 (old enumeration) on the Protozoa, and letter 22 on the discovery of the spermatozoa—two of the most important of Leeuwenhoek's communications to the Royal Society. The former was first published in full by Dobell in 1932. In it Leeuwenhoek records his discovery of bacteria, and many of his most striking observations on the Protozoa—a "truly amazing document" as Dobell describes it. All the letters are printed exactly as written, the Dutch and English versions with their appropriate footnotes and bibliographies facing each other verso and recto, so that translation and original can be compared without turning over pages. Letter 42 is followed by a list of those authorities who have assisted in clearing up difficult passages, and whose results are recorded in footnotes, and the volume is completed by a list of the weights and measures used by Leeuwenhoek, a bio-bibliography of authors cited, and author-subject indexes. The plates include photographic reproductions of such of the original drawings as have survived; but other modern figures necessary to illustrate the text and footnotes are added. As in the first volume the photographs of Leeuwenhoek's microscopes are not good, and that of the eel microscope could easily have been bettered.

When this work was projected by the Leeuwenhoek Commission it was recognized that the genius of this great Hollander could be justly honoured only if two conditions were satisfied: first, the publication *in extenso* of all recoverable manuscripts, accompanied by English translations; and, second, an exhaustive analysis of the texts to determine exactly what Leeuwenhoek had seen and discovered and to assess the historical value of such discoveries. It is perhaps too much to hope that the project can be completed in the opulent typographical style of the initial volumes, but we can at least be sure that the Commission will not go back on the main purpose of its adventure. That every effort has been put forth to secure perfection is evident in this stately volume. The editor himself would not claim that it is the last word, but he is to be congratulated on having laid an enduring foundation on which all future commentaries must rest.

One of the most difficult tasks in the interpretation of Leeuwenhoek's writings is the identification of the species on which he laboured. In some cases there can be no doubt, but in others the commentator must either admit that he does not know, or attempt a long shot, which may be wide of the mark, and in any event achieves only the dubiosity of intuition. The Dutch editors have adopted the latter alternative, and in doing so have thrown timidity to the winds. On p. 69 they identify a ciliate as *Holosticha* which it is true is probably a hypotrichid, but the species named by them on p. 71 as the "flagellate" (sic) *Prorodon*, and by Dobell as a "small ciliate", belongs obviously to the unidentifiable category. The *Oikomonas* attribution on p. 73 is also more than doubtful—in fact it is only probable that the organ-

isms in question were Protozoa. The interpretation of Huygens's figures of Protozoa as "various forms of *Stentor*" (p. 401) cannot be accepted, and Leeuwenhoek's "small" fluke in the sheep (p. 419) may have been *Dicrocoelium*; but a second infection of *Fasciola* is an equally if not more probable explanation. Both are known to occur in the sheep. The statement that the host "swallows the larvæ, the so-called rediæ, swimming in the flooded grass" will astonish the helminthologist. The following notes are suggestions for the file of addenda and corrigenda: p. 277, Roemer's English translation of letter 35, 1921, is omitted; p. 293, and elsewhere, Dalenpatius' name is misspelt; p. 303, the two references to Hooke relate to one and the same book with an added title in 1679; p. 411, line 7, for "suct" read "suet" (a baffling misprint); p. 449, Cl. Galen = clarissimus Galen, not Claudius; p. 453, the pulmonary circulation was known in the thirteenth century, Harvey is not responsible for the dictum "omne vivum ex ovo", he did not "discover the preformation theory" (which he would certainly have repudiated), nor (unhappily) did he "absolutely" reject spontaneous generation.

F. J. COLE.

[1] *Nature*, **144**, 956 (1939).

COSMIC RAYS

What are Cosmic Rays?

By Pierre Auger. Revised and enlarged American edition. Translated from the French by Maurice M. Shapiro. Pp. vii+128+22 plates. (Chicago: University of Chicago Press; London: Cambridge University Press, 1945.) 12*s*. net.

THIS little book gives a fascinating account of cosmic ray research, its results and its unsolved problems; the book is, indeed, an outstandingly attractive work on science for the non-specialist, and should appeal to the educated public that in recent years has so eagerly welcomed accounts of relativity, stars and atoms. Translation from the French has not obscured the clarity of the original version. The style is attractively light, with occasional wit, and thoroughly respectful to the intelligence of the reader—that is, it is sincere and free from any attempt at bemusement by paradoxes and verbal sleights; instead the author has striven with all needful skill and patience to enable the reader really to understand, not merely to create a fleeting illusion of understanding.

The story describes thirty years of research on a branch of science perhaps even more 'pure' than astrophysics, though like astrophysics it has made valuable contributions to general physics—in this case by the discovery of the positive electron and of mesons. Its sources in the depths of space are still mysterious, but great progress has been made in the study of the distribution of its impact upon the earth and of its transformations in the atmosphere and the ground; Nature has thus provided a laboratory for the study of particles and photons of the greatest known energy. Investigation of these natural experiments will incidentally lead to new advances in geophysics, and perhaps also in solar physics through the relationship of cosmic rays to the geomagnetic field and its disturbances, and to the changes of height-distribution of the air in the atmosphere; some of these topics already deserve more attention than is given in the book, though the original Paris edition of 1941 has been revised to bring it up to date, and new photographic illustrations have been added.

The book is well printed and produced, and to many readers its price, though much greater than that of the French edition, will seem extremely modest considering the charm and enthralling interest of the contents.

S. CHAPMAN.

ELECTRICITY FOR ENGINEERS

Elementary Electric-Circuit Theory

By Prof. Richard H. Frazier. Pp. ix+434. (New York and London: McGraw-Hill Book Co., Inc., 1945.) 4 dollars.

THE first difficulty with this text is its title; the author has gone so thoroughly into basic circuit theory that the term 'elementary' cannot be justified. A considerable experience of elementary circuits, both in theory and practice, by the student would, in Great Britain, be considered essential before this particular text could be accepted.

The very real and useful approach to the relationship between the fundamental essentials of electricity, as a subject in physics, and their application in the work of engineering is indicated by the following quotation from the book: "The engineer should be skilled in leading a double life—one in the concrete world of physical apparatus and one in the abstract world of ideas—and in interpreting each realm in terms of the other. If he can think only in terms of physical apparatus, he may become a useful mechanician but he lacks the analytical ability and the broad scholarly understanding of his field that should characterize a professional man. If he can think only in terms of abstractions, he may become a visionary whose ideas occasionally have practical possibilities but too often are nothing but play manœuvres with symbols."

The author certainly carries out these precepts in a highly personal way in the present text, which has none of the dry-as-dust explanations often regarded as desirable in a formal text-book. He is very apt in his applications, and the student is not spared any of the required processes of differentiation and integration; he has to take them in his stride. Vectorial treatment and even filter sections are not excluded, and there are numerous practical problems with which to exercise students.

It is extraordinary, however, that the general appreciation of such a text-book is marred by the observation that the author has certainly got Ohm's Law wrong, although the original publication of 1827 is quoted. At the top of p. 21 the sentence "Hence Ohm's Law and Joule's Law are interdependent; either can be derived from the other" cannot be accepted. Ohm's Law has nothing to do with circuits or the power-loss therein, which merely requires a definition of resistance as the voltage divided by the current. Surely Ohm's Law merely describes the physical phenomenon that for certain materials, in specified circumstances, such as constant temperature, no magnetic field, etc., the resistance of a conductor is constant and independent of the current therein. Perhaps in future editions Prof. Frazier will correct this slip, and while he will not make the volume perfect, nevertheless a striking imperfection will be removed.

L. E. C. HUGHES.

THE RELEASE OF ATOMIC ENERGY*

By Prof. M. L. OLIPHANT, F.R.S.
University of Birmingham

APPROXIMATELY fifty years ago the French scientific worker Bequerel discovered that certain minerals containing uranium possessed the property of producing energy in small amounts spontaneously, and apparently continuously. The Curies showed that the active substance responsible for this radioactivity in uranium minerals was not uranium itself, but was a small admixture of the rare element radium, which they were able to isolate. The activity of this concentrated material was so great that a mass of a gram of one of its salts maintained itself permanently several degrees hotter than its surroundings.

The disentangling of the complicated series of changes through which radium passes on its way to become lead was due almost entirely to Rutherford and his colleagues. Rutherford's youthful enthusiasm in Montreal was devoted to radioactivity. Nuclear physics, which he created, remained his one real interest throughout his life. The great advances in our understanding of this complex, submicroscopic subject, which has culminated in the atomic bomb, were all due to him and to that enthusiasm which he communicated to all who worked with him. It is interesting to notice that progress in this subject, which until now has been of purely academic interest, has been greater than in many branches of physics which are much more straightforward, but to which no Rutherford has devoted his genius.

Rutherford and his school established that the energy changes associated with radioactive transformations were very large in comparison with the energies associated with chemical change. It is customary in atomic physics to measure energies in terms of the energy acquired by an electron in falling through a potential of 1 volt—the 'electron-volt'. The energy associated with the motion of molecules is only 1 electron-volt for each 10,000° in absolute temperature, so that even in the surface of the sun, the average energy of atoms is less than 1 eV. The energy given out per atom of carbon (coal) burnt in oxygen is about 4 eV. The energy emitted by atoms as visible light is a few electron volts. In contrast with these the energy associated with radioactive change is millions of electron-volts. Indeed, inside the nucleus it is common to employ as the unit of energy 1 MeV. Realization that changes in the nuclei of atoms were accompanied by energy emission or absorption millions of times greater than are available in chemical reactions led at once to speculation about the possibility that this energy might one day be released for the use of mankind. Rutherford was always sceptical about this possibility, but success has come eight years after his death.

Rutherford and Soddy showed that the radioactive change which resulted in the emission of charged particles from the nucleus produced also a change in the chemical nature of the atom—the substance was spontaneously transmuted. There followed those brilliant researches, so simple in concept and so far-reaching in their results, by Rutherford and his collaborators, on the scattering of α-particles by matter. Thus he initiated the modern method of nuclear research, the bombardment of elements by high-speed particles. The first fruit of this study of scattering was the formulation, with Bohr, of the nuclear model of the atom. The second was the discovery in 1919 of the artificial transmutation of matter—the transmutation of nitrogen into oxygen by bombardment with α-particles.

Since that time nuclear physics has followed almost as a matter of course. It was in Rutherford's laboratory that atomic transformation with artificially accelerated particles was first achieved by Cockcroft and Walton in 1932, and there, in the same year, Chadwick discovered the neutron. These two discoveries led to spectacular advances, especially because the method of artificial transmutation gave large yields of neutrons.

The absence of electric charge rendered these new neutral particles very efficient agents with which to penetrate inside the nucleus, and Fermi showed that they produced transformations in the majority of the elements. It was the unsatisfactory nature of Fermi's conclusions about the reactions produced in uranium which led Hahn to make a detailed study of the products by chemical methods. Hahn, at one time a pupil of Rutherford, proved that the uranium nucleus, after absorption of a neutron, sometimes underwent a complete splitting into two single elements, so discovering the unexpected phenomenon of nuclear fission.

With this brief history in front of us, can we doubt that the modern release of nuclear energy is almost wholly the fruit of Rutherford's genius?

Bohr has given a simple and satisfactory qualitative picture of what happens when a neutron invades a nucleus. With Wheeler he has developed a model based upon the fact that the interactions between particles inside the nucleus, which he regards as made up of protons and neutrons, are so strong that an incoming particle must react with them all, that is, with the nucleus as a whole. This is in direct contrast with the action of a moving charged particle on the outer electronic structure of the atom, where, because of the loose interaction between them, individual electrons are excited to higher states, or are removed completely from the atom. In a nuclear collision which imparts energy to the struck nucleus the whole of the energy is shared among the particles, or in other words the nucleus is 'heated'. Because there are a finite number of particles in the nucleus there will exist well-defined energy levels for small or moderate excitations; but for an added energy of several million volts the system of levels will have crowded to a continuum.

For small excitation there may exist resonance levels for capture of neutrons; that is, over a restricted energy range, depending on the 'width' of the levels, the probability of capture may be extremely high as compared with that for energies on either side of these particular bands. If the energy of the neutron is large, or if the continuum of energy levels occurs for low energies, the probability of capture will not depend strongly on the kinetic energy of the neutron but will fall off slowly with increase of energy.

These models of neutron capture can be illustrated by the differences between the behaviour of the two isotopes of uranium, ^{238}U and ^{235}U.

* Lecture at the Royal Institution delivered on December 14.

The probability of capture by ^{238}U is vanishingly small for slow neutrons except for a pronounced resonance at neutron energy of about 38 eV. Capture of neutrons into this energy band produces a nucleus of mass 239. This isotope of uranium is unstable, emitting a beta-particle and transforming into an element of atomic number 93, or 'neptunium'. Neptunium itself is unstable and transforms, by emission of a further beta-particle, into element 94, or 'plutonium'.

$$^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{239}_{92}U \xrightarrow{e^-} {}^{239}_{93}Np \xrightarrow{e^-} {}^{239}_{94}Pu.$$

Plutonium is a comparatively stable substance. It is radioactive, emitting alpha-particles and transforming to $^{235}_{92}U$, with a half-period of a few tens of thousands of years.

$$^{239}_{94}Pu \rightarrow {}^{235}_{92}U + {}^{4}_{2}He + \text{energy}.$$

Neptunium and plutonium do not exist on earth because they are too short-lived to have survived, and there is no natural process by which appreciable quantities can be formed in uranium.

Uranium of mass 238 captures neutrons of energy greater than about 1 MeV., the neutron entering into the region of continuous energy levels. Bohr's picture of the process is then :

The uranium nucleus captures a neutron and becomes very 'hot'. The oscillations of the heated drop result in conditions which in a very short time lead to a splitting of the nucleus into two parts, the parts separating with tremendous energy. This is the phenomenon of nuclear fission, which was discovered by Hahn and verified by Meitner and Frisch. The break-up does not take place always in the same way and the relative masses of the products vary over a wide range, with a maximum probability that the ratio of the masses is about 2 : 3.

The energy with which the fission products separate is about 180 MeV. This energy is produced because the products together have a mass less than that of the original 'hot' composite nucleus, the mass ΔM which disappears being transformed into kinetic energy in accordance with Einstein's relation, $W = \Delta M.C^2$, where C is the velocity of light.

Uranium-235 differs from uranium-238 in that it is raised to a high enough state of excitation to undergo fission by the entry of a neutron of any energy. The probability of fission of ^{238}U for slow neutrons is large, varying with increasing energy inversely as the velocity.

Plutonium behaves in a very similar way, undergoing fission after capture of a neutron of any energy.

Thorium, like ^{238}U, undergoes fission as a result of the absorption of fast neutrons only.

In all cases the products of fission are themselves radioactive, emitting one or more beta-particles before becoming stable elements.

This simplified picture of the fission process is not complete. There are secondary products of fission, just as there is spray produced when a liquid drop is pulled apart, or dust when a stone is shattered. Joliot and his co-workers showed, shortly before the War, that these secondary products are neutrons, there being on the average more than two neutrons liberated per fission, the neutrons being ejected with an average energy of a little less than 1 MeV. This observation rendered it immediately obvious that a chain process was possible, since these neutrons could cause fission in other uranium nuclei. Provided the difficulty of competitive absorption of neutrons by ^{238}U could be overcome, it was clear that there existed the possibility of power production and of an atomic bomb. The problem reduced to one of technology and of the evaluation of the exact conditions under which chain reactions actually occurred.

Suppose we imagine a mass of pure uranium metal and try to understand what would happen to the neutrons liberated in a fission process occurring near the centre of the mass. The neutrons are not fast enough on the average to initiate fission of ^{238}U. The isotope ^{238}U is present in natural uranium only to the extent of 0·7 per cent—approximately 1 part in 140 of the metal. Consequently the probability of collision between these neutrons and ^{238}U is much smaller than for collisions with ^{235}U. The neutrons have a long free path, and unless the mass of metal is large they will escape from the exterior before they can produce fission in fresh ^{235}U nuclei. If the mass is very large and is extremely pure, so that the lifetime of neutrons is long because they are not captured by other substances, collision with uranium nuclei will reduce the energy slowly. The energy lost in a single collision is very small because of the large mass difference, and the neutrons will therefore hang about for a long time in any given energy state. The probability of capture into the resonance level of ^{238}U thus becomes large. There is likely, therefore, to be too great a loss of neutrons by absorption which does not lead to fission, for a chain reaction to be produced in a mass of uranium metal, however large, though this is not quite certain.

Two methods have been devised to ensure that a chain reaction will take place in a finite mass of uranium.

The first is to slow down the neutrons very rapidly by collision with some material such as heavy water (deuterium) or graphite (carbon) so that the chance of resonance capture by ^{238}U is reduced, and the probability of fission of ^{235}U is increased. Heavy water or graphite is used because neither captures neutrons readily, as does ordinary water. This gives a system operating on neutrons of thermal energy or thereabouts, and is probably the best procedure for power production.

The second method is to concentrate the ^{235}U so that the fast fission neutrons have a proper chance of producing a chain reaction directly ; or alternatively to prepare plutonium in quantity by first operating a slow-neutron reacting system. Such a fast-neutron chain reaction gives an extremely rapid multiplication of fissions and proceeds at a super-explosive rate—the atomic bomb.

The slow-neutron chain is best achieved with ordinary uranium metal by the use of graphite as a 'moderator' to slow down the fission neutrons. The arrangement used is a so-called 'heterogeneous pile', consisting of some tens of tons of uranium rods or slugs disposed in a calculated 'lattice' throughout a mass of some hundreds of tons of graphite, which is just a dense form of carbon. Fission neutrons which escape from one of the rods, in which there is a very

small chance of capture, pass into the graphite where, by successive collisions, they lose energy rapidly. The chance that they encounter a ^{238}U nucleus before they are slowed to energies below the resonance level is greatly reduced, and when the neutrons do diffuse to a uranium rod again they are readily captured by the ^{235}U and give rise to further fissions.

For the slow-neutron chain reaction to take place, the size of the system must be greater than a critical size, where the escape of neutrons from the surface is not greater than the rate of production. Some of the neutrons produced in fission are delayed, that is, they are emitted only after an interval of as much as one second. This means that for a system which is only just above critical size the exponential increase in the rate of fissions takes place rather slowly. By inserting into the pile rods of a material like boron or cadmium, which absorbs slow neutrons readily, the multiplication can be prevented altogether. Slow withdrawal of these rods allows the reaction to begin, and there is then plenty of time to reinsert them if the multiplication rises too rapidly. Adjustment of the rods can be carried out automatically by use of equipment like a thermostat, which sets the position of the absorbing rods so that the system runs continuously at any desired energy level.

The critical size of the system obviously depends upon the precise arrangement of the uranium and graphite and upon whether the surroundings reflect back any of the neutrons which escape from the surface. The fission energy is degenerated by collisions into heat, and the rods become hot. This heat may be extracted by cooling the rods, either by blowing gas such as air, hydrogen or helium, past them, or by surrounding them with a concentric tube through which water flows.

Unfortunately, uranium is very active chemically, and in particular it is very easily oxidized by contact with air or water. To prevent this the uranium rods or slugs must be coated with a layer of resistant metal which is in good thermal contact, but which does not absorb neutrons appreciably. There are very few metals which fulfil these conditions, and aluminium is the only one which has been applied in practice. It is necessary to keep the temperature of the air or water in contact with pure aluminium below about 100° C. in order that corrosion of the aluminium itself should not occur. Hence, at the present time, energy can be extracted only at temperatures of about 100° C., which is much too low for the operation of an efficient heat engine. The coating on the rods serves also to keep the products of fission from escaping into the cooling air or water. The fission products, which are highly radioactive, must be kept out of the machinery, pumps, etc., which have to be serviced, and must not be allowed to pollute the air or streams of water. The amount of heat which may be extracted from uranium rods or slugs is limited also by the low heat conductivity of the metal.

The size of the pile required to obtain a reacting system is obviously very large—how large can be judged from the fact that the first such system was built up on a squash court. The pile itself must be surrounded by coatings of graphite alone, to reflect back neutrons, and the whole enclosed in absorbing walls of concrete to prevent the escape of harmful radiations. Elaborate precautions are necessary to prevent accident. Materials inside the pile become so strongly radioactive that methods of handling them from a distance become essential, and all chemical operations on the uranium removed from the system have to be carried out in such a way as to prevent injury to the operatives by radiations from the accumulated fission products. Notwithstanding all these difficulties, piles have been operated at power levels of hundreds of thousands of kilowatts for months at a time.

The size of a reacting system can be reduced greatly by using uranium in which the concentration of the ^{235}U has been increased by partial separation of the isotopes or by adding another fissile element, for example, plutonium, to the metal.

Not all the neutrons in the pile escape capture by ^{238}U. There is a continuous production of plutonium, the concentration of which grows until it is destroyed as fast as it is formed. This plutonium, being chemically different from the uranium, can be separated from it by chemical methods. By suitable choice of the lattice the production of plutonium can be given an optimum value. This is the method used for producing plutonium in quantity. The rate of production of the element turns out to be about 1 kgm. per day for each million kilowatts of heat energy released. All this energy is dissipated at present to heat the Colombia River !

The possibility of using nuclear energy for industrial purposes clearly depends upon the solution of engineering and metallurgical problems of extraction of the heat at a temperature high enough for the efficient operation of heat-engines. There remains the question of the economics of the process as compared with the burning of coal or oil.

We have seen that because ^{235}U or plutonium undergoes fission for neutrons of any energy, a mass of such material which is large enough will develop an explosive chain reaction through the direct multiplication of the fission neutrons. Plutonium for the purpose can be produced in large 'piles', or ^{238}U may be separated from natural uranium by one of the processes, such as diffusion of a gaseous compound of uranium through a membrane, or by means of large mass-spectrographs, which have proved successful in the laboratory. Whether we require plutonium or ^{235}U, the plant is extremely large, complex and costly.

The critical size of a fast-neutron reacting system is far smaller than that of a slow-neutron system with ordinary uranium metal. The critical radius for a sphere of the material will clearly be of the order of magnitude of the free path of a fission neutron for capture by a fresh fissile nucleus, and this is of the order of 10 cm. The critical mass must then be of the order of 10–30 kgm. The critical mass will depend on the shape and the nature of the surroundings. A mass of fissile material which is smaller than the critical mass for the particular shape is perfectly stable. If two such masses are brought rapidly together the composite structure may be several times the critical mass, and if a neutron source is then activated inside the system the whole will immediately react violently. The time of passage of a fast neutron across the mass of fissile material is about 10^{-8} sec., so that in a microsecond or two the number of fissions will have multiplied to a stage where the temperature has risen to tens of millions of degrees and the pressure will have reached tens of millions of atmospheres. The glowing mass is far brighter than the sun itself and the radiation sears and scorches everything upon which it falls. The blast created by the expansion of the heated gases gives the great destructive effect.

SCIENTIFIC RESEARCH AND INDUSTRIAL PLANNING

BRITISH ASSOCIATION CONFERENCE

IT might have been too much to expect that the two-day Conference on Scientific Research and Industrial Planning arranged by the Division for the Social and International Relations of Science of the British Association on December 7 and 8, and held at the London School of Hygiene and Tropical Medicine, should reach the exceptionally high level of the similar conference on industrial research last January; and the Conference was neither so well attended as might have been expected, nor did it receive the publicity in the daily Press that it deserved. The latter is the more important, because the Conference as a whole had a far wider appeal than its general title suggested. In fact some of the speakers—and by no means those who like Prof. M. Polanyi have consistently warned their fellow men of science of the dangers inherent in planning science —seemed concerned rather to take the plan out of planning, and the general theme of the Conference was essentially the human element in research: the research worker himself and the conditions which are most likely to stimulate creative work; the place of the human factor in production and the contribution which scientific research can render to efficiency.

These were the main *motifs* in the Conference, and planning appeared to be discussed chiefly in regard to how best the community could organise its resources to secure the right type of scientific worker in adequate numbers and in the most fruitful conditions, and similarly how production could be most effectively organised in the service of human needs. In opening the first session of the Conference, in which "Fundamental Research in relation to the Community" was considered, Sir Richard Gregory said that the title and general plan of the Conference had been decided before the application of atomic energy to the construction of the bomb was made known last August. Sir Richard pointed out that the main subjects of the four sessions of the Conference—fundamental research, planned research, economic aspects and the human factor—were all considered in the joint statement on atomic energy made by the President of the United States and the Prime Ministers of the United Kingdom and of Canada in November, and the emphasis on freedom of thought and expression as an axiom of scientific inquiry which is formally accepted in the statement was repeated in Prof. M. Polanyi's address on the social message of pure science.

In a challenging address, Prof. Polanyi did much more than utter a further warning against the dangers of totalitarianism to which the planning of science is exposed. In criticizing the thesis that the content of science is determined by social needs, Prof. Polanyi undoubtedly over-stated the case—though scarcely to the extent suggested by a later speaker in the discussion, of setting up his own Aunt Sallys to knock them down; his plea that the essence of science is the love of knowledge, and that the utility of knowledge is secondary, was dignified and sincere. He pleaded that science is entitled to public respect and support as a pursuit of knowledge and of knowledge alone. The claims of science are a part of the claims of all scholarship for respect and for academic independence and freedom, and men of science are pledged to values more precious than material welfare. Moreover, Prof. Polanyi held that the world needs science to-day as an example of the good life, and he pleaded for the revival of international scientific life as a part of the restoration of reason and civilized human intercourse in Europe. He suggested that the United Nations should simply extend the privileges of diplomatic passage to men of science and scholars all over the world. With freedom to travel as they please through Europe, scientific men would restore within six months a close and intensive collaboration of all scientific workers in Europe, and weave once more a part of the destroyed European fabric.

Prof. Polanyi's vision of the wandering man of science restoring the broken unity of European civilization, with its call not merely to reassert the spirit of science and of scholarship but also to revive the spirit of reason and justice, gave dignity and purpose to an otherwise somewhat halting opening session.

Prof. J. W. Munro, who followed, did not seem quite sure of himself, and the chairman was equally at a loss to place the paper in relation to the theme of the session. The clue seems to be in the sentence with which Prof. Munro closed the account of his work on the fundamental problems of insect infestation, when he suggested that unless scientific men are free to follow their bent and study the problems that appeal to them, as he himself and Mr. Charles Elton had been, the scientific reserves for the attack on some of our urgent war problems would not have existed.

Prof. C. D. Ellis was also concerned with the practical aspects of fundamental research in relation to the community, and in particular with the implications of the recent discoveries in atomic energy. Holding that progress can only be assured if we have an ever-widening basis of fundamental knowledge and that pure research must have first priority, he proceeded to review briefly the practical results of these new discoveries. The outstanding achievement is the development of the 'pile', which means that nuclear chemistry is possible on an industrial scale; and if the difficulties in the way of utilizing the heat liberated in the process can be overcome, industry will have an immense increase in freedom of location, for there will be no fundamental difficulty in producing power in quantity in any place sufficiently accessible for the ancillary machinery to be assembled. This, he believes, is an important aspect to be kept in mind in planning the utilization of the new discovery; but no great reduction in the cost of power is likely and the use of nuclear power in driving ships or automobiles is unlikely to replace existing means of propulsion. Supplies of uranium are no more unlimited than those of coal or oil, and Prof. Ellis thought that the greatest benefits to mankind arising from the new discoveries may well lie in the widespread availability of radioactive materials of all atomic weights and their use in therapeutics and in research as indicators and aids in tracing biological and physical processes.

Sir Richard Gregory, in opening the discussion, emphasized that the essential motive of men of science is the discovery of truth, and that science is to be

understood as systematic or organized knowledge in any field of human activity and not merely in the study of natural phenomena. Prof. A. G. Tansley, pointing out that fundamental research is not easily defined and that too much should not be made of the distinction between pure and applied research, the distinction depending rather on the subject than the method, stressed the importance of freedom and endowment: endowment of fundamental research should not be subject to control outside the ranks of scientific men themselves. He also referred to the demonstration in the war effort of the possibility of combining team-work and individuality.

Mr. Herbert Morrison, Lord President of the Council, who opened the afternoon session on "Planned Research", also stressed this element of freedom. The close working partnership between the Government, scientific men and industry which grew up during the War was indeed a partnership and not the regimentation that had proved disastrous in Germany. Science has a vital contribution to make to that increased productivity on which social progress and security depend. While we have no reason to be ashamed of our record in pure science, he thought that before the War we were not bold enough in applying the results; we must look to the development of whole industries. After suggesting that in regard to new knowledge we should attempt to free workers from economic handicaps and encourage them to pursue knowledge for its own sake, Mr. Morrison urged that in the wider field of applied science we should provide the right atmosphere and tools. We should provide the wide incentive of social purpose instead of the narrower though not irrelevant incentive of profitable exploitation. Priorities for development and application should be fixed in the public interest and in relation to the quickening of the general economic plan, within which scientific research would find its aims and inspiration, and in which national problems and public needs would be the guides and targets for the efforts of every section of the community. The educational policy of Britain must provide for the training of adequate numbers of scientific workers and of laboratory assistants, and besides providing adequate endowments for research we must encourage the employment of men of science in the Civil Service as well as in industry. Above all, in a world safe from war, planned research involves the fullest freedom for the exchange of ideas and results not only among scientific workers themselves but also between them and industry and Government.

In this reference to the importance of closer contact and better information services, Mr. Morrison pointed out that the committee he has recently appointed to consider the use and development of the scientific man-power and resources of Britain includes besides three men of science, an administrative Civil Servant, an economist and a business man.

Sir Edward Appleton, who followed Mr. Morrison, pointing out that planned science means deliberate and conscious planning for application, said that there are two aspects: the choice of objective, and the means by which it is to be achieved. The public is fully aware now of the social consequences which might come from scientific discovery, and he finds that young people, in consulting him regarding the choice of a career, are frequently determined by the probable social or political consequences of the work they are contemplating. Now that Government has increasingly come to assume the positive function of ensuring that the right things are done, its function in planned research should be to secure a proper allocation of effort. Academic research which is solely concerned with the advancement of knowledge should be free from any conditions or effect of the by-products of that work, and any planning should merely ensure that enough money is available for the work to go forward. In industrial research, we are planning for practical objectives, but Sir Edward considers that the results obtained in the Department of Scientific and Industrial Research should be made available for all, and that we must take care to avoid short views in objective planning. He urged the importance of long-term objectives in fundamental research in the physical sciences. In conclusion he uttered a warning against the danger of putting scientific workers on too high a pedestal. The authority of science does not extend beyond its own sphere, and he is of opinion that scientific men should be careful to claim no special privileges and to avoid attempting to dictate how their results should be used.

Dr. C. F. Goodeve, speaking on planning and organizing research, suggested that the first lesson of the War is that proper planning and direction of background and applied research are essential: practically the whole of the technical advances of the War were made under a system of extensive planning and direction. Next, he suggested, we have learnt that a research organization must be such that it can seek out and ascertain accurately the objectives in the given field of activity, and inspire every man in the organisation with their importance. As a corollary of our war experience here, Dr. Goodeve pointed out that scientific workers will require full knowledge of the economic and commercial aspects of their work. Next comes the importance of the right degree of collaboration with the user. Such collaboration both clarifies the objective and eases the problem of utilizing the results of research, but it is essential that the user should understand what is involved. Dr. Goodeve then referred to the question of team-work, the organisation of which is a major task of a research director. There must also be a balance between background research and development, and priorities should be determined not merely on the strength of a particular need but also on the prospects of meeting that need in the required time.

Dr. E. F. Armstrong had prepared a paper on "Planned Research in the Building Industry", which was read for him. Reviewing the special problems encountered in an industry like building, which is largely based on traditional practice, Dr. Armstrong indicated the way in which research on building requirements, materials and structures and on the industry itself, covering human efficiency and social surveys and laboratory studies involved in the functional aspects of buildings, is already being planned to solve one of the most fundamental problems of our age—the synthesis of suitable building for a modern civilization. Sir William Larke, who opened the discussion, commented on the need for the widest and most efficient organisation for ensuring the prompt application of the results of research throughout the industrial economy of Britain. He would build on to the Department of Scientific and Industrial Research a national council widely representative of scientific and industrial interests and empowered to promote and finance through existing organisations, or under its own direction, research into fundamental problems

which have far-reaching effects on the economic life of the country and the standards of life, but which could not be solved so quickly by any one country acting alone. Such a national council might delegate detailed responsibility for international collaboration to appropriate existing bodies, but would endeavour to expand and develop existing research facilities and establish new research organisations where facilities are not available; and it would provide a central national source of information and inspiration relating to research which is badly needed. We must above all get away from the contemptuous attitude to research. Dr. P. Dunsheath referred to the danger of over-developing ideas, but his remarks on planning as affected by human personality linked the second session with the third and fourth, dealing with the economic aspects of research and with the human factor, respectively, but in both of which the human aspects were almost equally prominent.

Lieut.-Colonel Urwick's inspiring chairmanship quickly opened up the wider horizons at the morning session on December 8 in his opening remarks, when he pointed out that the economist and the engineer have both much to learn from each other, and that we need to pay much more attention to the principle of balance in industrial and in social organisation. Scientific knowledge is badly out of balance with an appreciation of the importance of applying such knowledge to the solution of social and economic problems, and the scientific worker, the administrator and the financier should come together in assisting the Government to solve some of the problems of society and to achieve an integration of authority and responsibility in which all could share. Prof. P. Sargant Florence, dealing with the economic stages involved in the transmutation of ideas into products, argued that scientific research can be applied to such stages just as in the natural sciences, and that such research can similarly be developed at the universities, in scientific institutions and in industry itself. The chart of the contribution of the human sciences to production problems with which Prof. Florence illustrated his paper shows how unevenly such efforts have been distributed, although scientific methods have been already applied in each of the four groups of problems he distinguished, namely, industrial economics, production engineering, industrial psychology and production management. A body of knowledge is in fact being accumulated, which should be pooled for the benefit of all producers; and which when organised sufficiently to generalize and interpret deserves teaching at the university level. This is a vital factor in laying the foundation stone for higher standards of leadership in industry and commerce; and Prof. Florence linked this further call for higher standards of industrial management with a plea for more published pooled research in production engineering and management, in which Great Britain lags behind. Such problems must be tackled in a scientific spirit and by scientific methods, for their scientific handling is an essential factor in furthering national efficiency in getting into large-scale production, upon which an increased export trade and improved standards of living depend.

Mr. F. E. Smith, of Imperial Chemical Industries, Ltd., who followed, based his remarks on the view of research as the process of gaining knowledge in a systematic manner by the study of phenomena or by the examination and correlation of existing data, and further that the economics of research can only be considered in relation to human life. Mr. Smith suggested that industrial research is of two main types: that directed to maintaining the competitive position of the firm in its established products, and that directed to the development of new products. He referred to the neglect of scientific research and method on both the technical and human sides in distribution and other important non-manufacturing industries. Research on a proper scale is essential for efficient working; but it is important that it should be properly directed and its results should be properly applied. Here endorsing Dr. Goodeve's observations on the overlap between fundamental, background and development research, Mr. Smith emphasized that we need a better balance between research into the physical and into the humanistic sciences, and that fundamental research should not be shut off. We must encourage the diffusion of scientific knowledge by the interchange of scientific workers between industry, the Department of Scientific and Industrial Research and other Departments and the universities, as well as by more effective organisation of information services. Industry, besides its research staff, requires many more men who are qualified by education and training to appreciate the value and place of research and development, production and user departments in their respective fields, if we are to overcome the lag in the application of new knowledge which has sometimes characterized Great Britain.

Prof. M. L. Oliphant said that the scientific worker was jolted out of his 'ivory tower' before and during the War, and referred particularly to the necessity of obtaining scientific equipment for fundamental research from abroad owing to lack of enterprise in Britain. He made a vigorous appeal for a more adventurous spirit. Britain's ability to throw up great scientific workers is one of her biggest assets; but there is at present grave danger that excessive caution may lead to the centre of research and development shifting to other countries. Deploring the existence of short-term views, he urged that it is impossible to direct scientific energies; the universities should endeavour to get the research spirit into applied science and build up the proper background of science for the production engineer, and leave him to apply it. Dr. Rosin said that insufficient attention is paid to the fundamental principle of research—the proper definition of a problem. The achievements of research in the War were obtained in complete disregard of the common concept of economic research: the determining factors were man-power and materials, not finance. Prof. J. D. Bernal commented on the need for integration, and on the possibilities of infiltration of scientific ideas into our thought. Social, rather than economic, objectives are required. He criticized defects in the British patent system and referred to the importance of developments in industrial psychology particularly with reference to training. Summing up, Lieut.-Colonel Urwick pointed out that the management of research has two main aspects: the relations between research and management, and research into management itself. We need a partnership on equal terms between the research worker and the administrator. Fundamentally, the economic aspect of research is a problem in thinking. The obstacles are essentially human obstacles, and by right thinking they could be overcome.

The morning session thus led smoothly to the final session on December 8, over which Dr. Raymond Priestley presided. Dr. Priestley, viewing the problem

in relation to the discovery and education of research workers, said that in regard to the outstanding first-class man the problem of securing the best use of the nation's resources involves seeing that he gets to the top quickly and in the right place, and he looked for at least a couple of dozen centres of learning and research with internationally recognized schools in several fields. More of our outstanding men should also be attracted to our research institutes and industrial research laboratories. For the great majority, who represent the second class of research worker, we need more postgraduate studentships and research fellowships and freer circulation between university laboratories and research organisations in government and industry, and franker and more frequent discussion and pooling of results. Finally, we need much more adequate provision of technical assistants of all kinds, with better conditions of service and prospects of promotion. This is at present one of the universities' weak spots, as has indeed been emphasized in reports on the universities and research. In conclusion, Dr. Priestley said that he would like to see imported into the education of the man of science at a fairly late stage some element which would force him to think about and study the history of the world in which he lives.

Sir Arthur Fleming's paper discussed from the industrial point of view the functions with which the research worker has to deal. He regards the function of research itself in industry as the achievement of the utmost efficiency in the industrial transformation of raw materials into finished products; and he urged that it is essential that in every manufacturing concern there should be an officer who could assimilate, interpret and apply, as it became available, the scientific knowledge appropriate to his concern's field of industry. The industrial research worker requires to know a good deal about the economics of the problem, the limitations to manufacturing processes and something of industrial administration and markets. Judgment and courage are involved in regard to the introduction of new tools, processes or materials; and the human factor is also important in the education of public opinion, where interest awakened during the War should be developed to ensure that a strong and healthy public opinion encourages the application of scientific research in all services affecting the public.

Mr. Alec Rodger, senior psychologist at the Admiralty, dealing with the contribution of the industrial psychologist to industrial reconstruction, pointed out that the psychologist in general suffers somewhat from misunderstanding and from lack of official recognition. Industrial psychologists are also very scarce—there are only about thirty among the fellows and associates of the British Psychological Society, and we should aim at increasing this number to at least 120 during the next five years. Training facilities are also extremely poor. He would like to see the National Institute of Industrial Psychology become a live centre of postgraduate training linked closely with the University of London, and making its contribution to the training of personnel managers, employment officers, careers masters and others. Moreover, the industrial psychologist is inevitably an advocate and agent of scientific management, and Mr. Rodger thinks he cannot make his maximum contribution to social and economic life until a full employment policy is implemented and we have a planned wage structure for the whole of industry. That contribution during the next two or three decades would best be made if industrial psychologists concentrated on the problems of vocational guidance and personnel selection methods of training and the design and lay-out of equipment.

Mr. J. T. Kendall, discussing the education and training of the research worker, suggested that more attention might be given to the needs and weaknesses of the men and women to be trained, and referred to such ideas as postgraduate or refresher courses and increased migration between the academic and industrial world as important in bridging the gulf which sometimes develops in Great Britain between pure and applied research. With regard to the basic psychology of research, he pleaded that place should be found in the training of the research worker for some instruction in the art of thinking, and that any training in technology for the applied scientific worker should be deferred to the postgraduate stage. He also urged the need for a broad general education designed to fit the scientific worker to take an active interest in everyday affairs. This clearly should be given largely at school, where specialization should be avoided; but in part it must come from informal education. To increase substantially the number of first-class men of science, we must aim at a general increase in the level of education and standard of living of the nation. Prof. Bernal referred to the importance of freedom. Creative activities and original thinking cannot be carried out under compulsion, and he pleaded for the association of those who believe in planning with those who feel most strongly about the freedom of science. It should be possible to use people largely to solve the problems in which they are interested and which they wish to solve. Referring to the value of the method of discussion and organised collaboration demonstrated in war research, he emphasized that the organisation of science must be democratic, and one object in our organisation must be the selection or determination of priorities. On this point Mr. J. A. Lauwerys, observing that personnel constitutes a bottleneck in the expansion of research, referred to the relation of teaching to the output of scientific workers, and emphasized the need for seeing that the release and training of teachers is handled as a priority of the first order.

The concern regarding the future use of atomic energy which had been manifested throughout the Conference, from Sir Richard Gregory's opening speech and particularly in the addresses of Prof. C. D. Ellis and Prof. M. L. Oliphant, found expression in a resolution approving the statement of President Truman, Mr. Attlee and Mr. MacKenzie King, which was passed at the end of this final session. The resolution, affirming the belief of the Conference that the statement "should receive the support of the scientific world as indicating the true approach to the problems of developing the beneficial applications of atomic energy and other scientific achievements on the one hand, and, on the other, of preventing their destructive uses", requested the Council of the British Association "to consider the desirability of forwarding a communication to H.M. Government in this sense, and of using any other opportunity within the scope of the Association to support the ideals implicit in the statement". Sir Richard Gregory, in moving the resolution, stressed the indispensable condition of full freedom for science and the impossibility of stopping the advance of knowledge; and he urged that the scientific worker, as a citizen, desires only peaceful and productive issues to his discoveries.

SCIENTIFIC CENTENARIES IN 1946

By Engineer-Captain EDGAR C. SMITH, O.B.E., R.N.

THE international character of science which has been so often referred to by eminent men and so frequently stressed in the pages of *Nature* is well illustrated by the centenaries of distinguished investigators in physical science which occur in 1946. Disregarding for the moment the tercentenary of the great German scholar, philosopher, diplomatist and mathematician Leibniz, the year recalls first a succession of astronomers of many nationalities from the days when men's views were coloured by the mysteries of astrology and the dogmas of religion, and when there were neither scientific journals nor societies, much less international gatherings.

Foremost in the list of men to attract attention is Tycho Brahe, famous for all time for his laborious observations, which were used by Kepler in the unfolding of the laws of planetary motion. Noble by birth, independent in character, vehement in manner and cast in heroic mould, Tycho was of Danish nationality though born in Knudstrup near Lund in Sweden. His birthday was December 14, 1546. He was well educated and was intended for the law; but as with so many others, a solar eclipse—that of August 21, 1560—determined all his future actions. At Copenhagen, Leipzig, Wittenberg, Rostock, Basle, Augsburg and Cassel he followed his bent, making a reputation which led in 1576, when he was thirty, to his being put in possession of the little island of Hven, situated in The Sound and not far from the romantic castle of Elsinore. Here he built his famous 'City of the Heavens', the Pulkovo of the day. With ample means provided by his patron, King Frederick II of Denmark, he worked there steadily for twenty years, determining the places of the moon, the planets and the stars as accurately as he could with his simple sextants and quadrants. Then less happy times befel him, and in 1597 he left Denmark never to return, and died an exile at Prague on October 24, 1601, at the age of fifty-four, leaving Kepler his mass of observations and his new planetary tables.

The foundation of Tycho's 'Uraniborg' was laid on August 30, 1576. Just a hundred years later, on October 29, 1676, the Rev. John Flamsteed, appointed by Charles II "our astronomical observator", began his observations at the Royal Observatory, Greenwich. In 1676 Flamsteed, like Tycho in 1576, was thirty years of age, having been born on August 19, 1646, at Denby, seven miles from Derby. At Greenwich there was none of the magnificence of Uraniborg. Built partly with materials from Tilbury Fort and the Tower of London, and costing not much more than £500, the Observatory, it is true, was designed by Wren; but when Flamsteed took up his residence there, it was bare of instruments, which the first Astronomer Royal had to provide out of his meagre salary of £100 a year. Lack of means and ill-health dogged Flamsteed's footsteps all his life, and these probably had something to do with the unfortunate quarrels which arose between him and Newton. But in spite of all disabilities, he pursued his course unswervingly, carrying out his instructions "forthwith to apply himself with the most exact care and diligence to the rectifying the tables of the motions of the heavens and the places of the fixed stars so as to find out the so much desired longitude of places for the perfecting of the art of navigation". Though none of his instruments have been preserved, the Observatory has a mural arc similar to that made by Flamsteed and Abraham Sharp at a cost to the former of £120. One of the outcomes of the dissensions which arose between Flamsteed and the Royal Society was the appointment in December 1710 of the Board of Visitors. Among their duties was that of reporting on the state of the instruments; seeing that these belonged to the Astronomer Royal it is easy to understand his chagrin.

The financial position of Flamsteed had been improved somewhat in 1688 by a bequest from his father, and four years earlier by his appointment to the living of Burstow, about three miles south-west of Horley, Surrey. A long straggling parish, Burstow has no central village, and the pleasant little church is surrounded by land which in Flamsteed's time must often have been flooded. His journeys between the rectory and the Observatory were, it is presumed, made on horseback; but of the performance of his parochial duties little appears to be known. At his death on December 31, 1719, he was buried in the chancel of the church, and later on his wife was laid beside him. They both left money to provide annually coats for two worthy men and gowns and petticoats for two worthy widows. For 168 years no memorial marked the Astronomer Royal's burial place, until in 1887 the late J. J. Tustin, of Burstow Hall, gave the stained glass window in the east of the chancel and a tablet to remind visitors where Flamsteed rests.

The next astronomer in the list is Giuseppe Piazzi, the Italian Theatine monk who was born at Ponte in the Valtoline, north Italy, on July 16, 1746. After he had been a student under many famous masters and a teacher in several cities, he was appointed in 1780 by Ferdinand II, king of the Two Sicilies, to be professor of mathematics at Palermo, where he was able to erect an exceptionally well-equipped observatory containing one of Ramsden's finest instruments. His discovery on the first day of the nineteenth century of the first of the asteroids, Ceres, was the outcome of plans to search the skies for a planet believed to revolve in an orbit between those of Mars and Jupiter. Twenty-four astronomers, mostly German, were to take part in the search, and Piazzi was to be one of the twenty-four; but he made his discovery before receiving his nomination. Like so many others, he published a catalogue of stars, his containing 6,748 stars he had observed at Palermo. He died at Naples on July 22, 1826.

Freidrich Wilhelm Bessel died on March 17 a century ago, his life overlapping the eighty years of Piazzi's by forty-two years. His birthplace was Minden, the scene of the famous battle of 1759. One in the family of nine of a minor Civil Servant, Bessel was apprenticed to a business firm in the port of Bremen and looked forward to becoming a supercargo of a sailing ship. The study of mathematics, navigation and astronomy, however, led to his acquaintance with the benevolent Bremen physician and astronomer, Olbers, and from that time ships became of secondary importance. When he was twenty-two, he became assistant to Schrötter, 'the Herschel of Germany', and four years later he was made professor of astronomy in Königsberg and also director of the new observatory which, it was said, "will ever remain a monument to his glory no less than to the munificence of the Sovereign [Friedrich Wilhelm III of Prussia] who, amid the alarms of war and the desolation of his country, still mindful of science, ordained its institution".

Charles II, Frederick of Denmark, Ferdinand of the Sicilies and Friedrich Wilhelm of Prussia are but four of scores of rulers and princes who in the past gave their royal support to the erection of observatories; to-day their places have been taken largely by wealthy commoners, millionaires such as James Lick and Charles Tyson Yerkes of the United States. American colonists had their telescopes and sent their observations to the Royal Society in its earliest days. But the first real observatory on the western side of the Atlantic was that erected by David Rittenhouse, F.R.S., at Norriton, twenty miles from Philadelphia, in 1768. It was, however, much later that astronomical studies made rapid headway in the New World. The Harvard Observatory was founded in 1840 with W. C. Bond as director, and the Washington Naval Observatory, where Maury worked, in 1842. Since then American observatories have sprung up rivalling Tycho's Uraniborg, and astronomy has a great following. In his book "Astronomers of To-day" (1905), Macpherson, out of his thirty-two biographical notices, devoted no fewer than nine to Americans. This will partly explain why in the list of centenaries during 1946 are found the names of Edward Singleton Holden (1846–1914), the first director of the Lick Observatory; of Seth Carlo Chandler (1846–1913), the editor of the *Astronomical Journal*; of Lewis Boss (1846–1912), of the Dudley Observatory, Albany, New York; and of Edward Charles Pickering (1846–1919), director of the Harvard College Observatory. All four were associates of the Royal Astronomical Society and three of them gold medallists of the Society. Another associate of the Society and also a foreign member of the Royal Society, born in 1846, was the distinguished Swedish astronomer Johan Oscar Backlund (1846–1916), who in 1895 succeeded Bredikhine as director of the great Russian observatory—now destroyed—at Pulkovo, a few miles south of St. Petersburg. He had become a naturalized Russian some years before.

The year of the birth of Flamsteed was also the year of the birth of Gottfried Wilhelm Leibniz, "le savant le plus universel des temps modernes". Endowed with extraordinary powers of mind, "He may be said," wrote Prof. A. C. Fraser, of Edinburgh, "to have founded in the course of his life the European commonwealth of letters, and to have restored in part that community of intelligence in Christendom, of which the universities were the organ, until the Reformation dissolved their organic unity." His invention of the calculus and the bitter controversy which raged for a long period were reviewed in "A Short Account of the History of Mathematics" (1901) by W. W. Rouse Ball, who said that Leibniz's "title to fame rests on a sure basis, for by his advocacy of the differential calculus his name is inseparably connected with one of the chief instruments of analysis, just as that of Descartes—another philosopher—is with analytical geometry". Germany was greatly indebted to Leibniz for his foundation in 1682 with Otto Mencke of the scientific journal *Acta Eruditorum*, and for the inauguration in 1700 of the Berlin Academy of Sciences. Born in Leipzig on June 21 (O.S.), 1646, he lived at Nuremberg, Mainz, Paris, and other places, his headquarters from 1676 being Hanover, where he was keeper of the ducal library. "On the accession in 1714," says Ball, "of his master George I, to the throne of England, Leibniz was thrown aside as a useless tool; he was forbidden to come to England; and the last two years were spent in neglect and dishonour." He died at Hanover on November 14, 1716.

A name famous in the annals of science in Scotland is that of Colin Maclaurin, F.R.S., who died at York on June 14, 1746, his death being due to exposure in the trenches at Edinburgh during the 1745 Rebellion. Born at Kilmordan in February 1698, he was made professor of mathematics in Marischal College, Aberdeen, at the age of nineteen, and six years later succeeded the second James Gregory in the mathematical chair at Edinburgh. His treatise on fluxions appeared in 1742, and his "Account of Sir Isaac Newton's Philosophical Discoveries" posthumously in 1748. Maclaurin served his country and friends in many ways.

Among the men of science born in 1746 were George Atwood, F.R.S. (d. 1807), of Trinity College, Cambridge, writer, lecturer and experimenter, whose paper to the Royal Society on "Determining the Positions assumed by Homogeneal Bodies which Float Freely and at Rest" gained him the Copley Medal for 1796; Jacques-Alexandre-César Charles (d. 1823), who made aeronautical history by the introduction of the use of hydrogen in balloons and was professor of physics at the Conservatoire des Arts et Métiers; Giovanni Battista Venturi (d. 1822), professor and engineer at Modena, whose name is perpetuated by the 'venturi meter' invented in 1888 by Clemens Herschel of Holyoke, Mass.; and Gaspard Monge, Comte de Péluse, creator of descriptive geometry, a founder of the National Institute and the École Polytechnique in Paris. One of the most prominent men of science in the Napoleonic era, Napoleon's fall meant disaster to Monge, and his dismissal from the Institute was a blow from which he never recovered.

So much for 1746; what of 1846? That year there was fighting in India, riots and famine in Ireland, trouble in Mexico, and revolution in Poland and Switzerland. But none of these events excited the interest or disturbed the peace of the world of science as did the discovery of the planet Neptune. The predictions of Adams and Leverrier, the oversight of Challis and Airy and the success of Galle were discussed everywhere. Before Galle saw the planet, Sir John Herschel had declared in his picturesque way that "We see it as Columbus saw America from the coast of Spain. Its movements have been felt trembling along the far-reaching line of our analysis with a certainty hardly inferior to that of ocular demonstration." The observation of the planet on September 23, as Miss Clerke said, dissipated "the last lingering doubts as to the universal validity of the Newtonian Law!". But again controversy arose, again national bias, incomplete knowledge and hasty conclusions showed that even men of science are not without their human weaknesses. Yet nothing could dim the glory of an achievement which was the subject of many eulogies: as a young professor, Lord Kelvin used to devote three pages of manuscript in his inaugural lectures to the discovery of Neptune, until Tait told him the subject had been "ridden to death".

Reverting to the main theme of this article, the centenaries of men and not of events, 1846 saw the passing of the German astronomers and physicists Johann Friedrich Benzenberg and Christian Ludwig Ideler, the latter a foreign associate of the Paris Academy of Sciences, and of Dr. Ernst Alban, the pioneer in Germany of the use of high-pressure steam in engines. The death of the English chemist James

Marsh, for long the assistant at Woolwich to Faraday, who from 1829 to 1851 was professor of chemistry at the Royal Military Academy, saw the close all too early of an ill-requited career, while the death at Chorlton-upon-Medlock of the manufacturer John Owens made available according to his will more than £90,000 for the foundation of an educational institution in Manchester. The well-known Owens College was opened in 1851, and from it sprang the University of Manchester.

Finally come the men of science and engineers from many lands who were born a century ago, and who in some cases were associated with those still living. Ira Remsen, the American chemist, who died in 1927, was of Dutch descent. He worked in laboratories in Germany, being a fellow student with Sir William Ramsay at Tübingen, and in 1876 became the first professor of chemistry at the newly founded Johns Hopkins University, of which he ultimately became the president. In 1898 he was made a foreign member of the Chemical Society. While Remsen taught at Baltimore, Sir William Hartley, F.R.S., held the chair of chemistry in the Royal College of Science, Dublin. Known especially for his work in spectroscopy, he was a founder and the first president of the (Royal) Institute of Chemistry. He died in 1913, having been knighted two years before. Men of science in Poland have often worked under discouraging conditions, and this was the case with Karol Stanislav Olszewski (1846–1915), one of the leading investigators of low-temperature phenomena and the liquefaction of gases. He had lost his father in the insurrection of the peasants in 1846, but was able to qualify as a chemist under Bunsen at Heidelberg. He was then given the chair of chemistry at Cracow, where all his work was done. In more peaceful Denmark, Poul la Cour (1846–1908) devoted himself to meteorology, and for a time was director of the government wind-power station at Askov, in Jutland. He was an inventor of scientific apparatus and edited Tycho Brahe's diary of 1582–96. Meteorology also claimed the attention of the Rev. John Mackenzie Bacon (1846–1904), of Trinity College, Cambridge. He went on eclipse expeditions, studied acoustics, took to kite-flying and ballooning and was a lecturer of distinction.

Various branches of engineering are recalled by the names of Durston, Watts, Westinghouse, Canet and Brandt. Engineer Vice-Admiral Sir John Durston (1846–1916) and Sir Philip Watts, F.R.S. (1846–1926) were both trained in the Royal Dockyards and the Royal School of Naval Architecture and Marine Engineering at South Kensington, Durston rising to the position of engineer-in-chief of the Fleet, while Watts from 1902 until 1912 was the director of naval construction and as such the designer of the famous battleship *Dreadnought*. George Westinghouse (1846–1914), who had German, Dutch and British blood in his veins, was one of the great figures in American engineering. When given the Grashof Medal by German engineers, the citation referred to him as "the pioneer of the automatic brake, the successful protagonist of alternating current, the meritorious designer of high-speed engines". Westinghouse was an industrialist on the grand scale. Jean-Baptiste-Gustave-Adolphe Canet (1846–1908) was as well known in the artillery world as was Westinghouse in the railway world. When he died he was president of the Junior Institution of Engineers, which founded the Gustave Canet Memorial Lecture in his honour. A different sphere of engineering is recalled by the career of Albert Brandt (1846–99). Born in Hamburg, he was a student in Zurich in the days of Zeuner, Culmann and Clausius. In 1875 he assisted in the construction of the St. Gothard Railway, and three years later entered into partnership with his countryman Karl Brandau (1849–1917). To Brandt and Brandau, together with the Swiss engineer Dr. Eduard Locher-Freuler (1840–1910), belongs the credit for the construction of the great Simplon Tunnel referred to by Prof. (now Sir) C. E. Inglis in a broadcast on October 25, 1942, as "the greatest epic in civil engineering history" and "the most courageous victory ever won by engineers in their never-ending conflicts with the forces of Nature".

WILLIAM CURTIS

WILLIAM CURTIS, founder of the *Botanical Magazine* and author of "Flora Londinensis", was born two hundred years ago, on January 11, 1746, in Alton, Hampshire. The bicentenary of his birth is being celebrated, fittingly enough, at his birth-place, by an exhibition of manuscripts and other 'Curtisiana' to be opened on January 11 at the Alton Assembly Rooms, adjoining the Curtis Museum, of which Mr. W. Hugh Curtis, author of "William Curtis" (1941), is a joint honorary curator.

William Curtis was the son of a tanner of good Quaker family, and after leaving school was apprenticed to his grandfather, a surgeon-apothecary practising in Alton. William's early love of wild life was stimulated at this time by the ostler at the Crown Inn, one Thomas Legg, in whose company he searched the country round for plants and insects. His grandfather, however, disapproved of this deviation from the narrow path of an apothecary's curriculum, and William was packed off to the less tempting surroundings of London. Here he pursued his studies and in a short time inherited a business of his own in Gracechurch Street. But natural history was his first and true love and in 1771 he sold his practice and acquired an acre of land in Restoration Spring Garden, Bermondsey, for the culture of British plants. Various other projects, including the "Flora Londinensis", were already seething in his head, and he was now fairly launched on a botanical and entomological career. British botany at this time was badly in need of recruits. The Linnean system had recently been introduced into the country and workers were wanted to re-examine the British flora with a vigour and concentration that had been lacking since the death of Ray in 1704.

Curtis, in 1771, was already closely in touch with many of the leading British botanists, but in 1772 he acquired official status among them by his appointment as *Praefectus Horti* at the Society of Apothecaries' Chelsea Garden—a post he held until 1777.

Curtis's earliest two publications were entomological ("Instructions for Collecting and Preserving Insects", 1771, and a translation of Linnæus's "Fundamenta Entomologiae", 1772); but during his time at Chelsea, plans for his great work, "Flora Londinensis", were maturing, and the first number was issued in May 1775. Publication in parts continued until 1798, though not without the delays and complaints from subscribers that seem inseparable from such a method, and which Curtis's rather unbusinesslike disposition did nothing to mitigate. The two volumes in which the work is usually seen to-day

appeared in 1777 and 1798. Curtis's aim was to produce a complete Flora of Britain, towards which the "Flora Londinensis" was to be a modest beginning; but the larger idea is represented only by a few non-London species included towards the end of the work. To the general public, then as now, the chief attraction of the "Flora" is the series of magnificent coloured plates, 435 in all, drawn and engraved by Sydenham Edwards, Kilburn, Milton, Sansom, James Sowerby and others. Three hundred copies of each part were printed and the plates were hand-coloured by a team of some thirty colourists. But the text, to the botanist, is of equal or greater value. Sir James Smith ranked it "next to Ray's *Synopsis* in original merit and authority on British plants". Curtis was an acute and thorough worker, and in many difficult groups he brought order out of chaos, interpreting old names in the light of recent knowledge and describing several new species.

It is scarcely surprising that the severely botanical "Flora Londinensis" was not financially successful, and during its publication, in 1787, Curtis launched his second great venture, the *Botanical Magazine*, which recouped him handsomely for his losses. The *Magazine*, said Curtis, brought him pudding, while the "Flora" brought him praise. His aim, as described in the preface, was a work "in which Botany and Gardening . . . might happily be combined", and the fact that the magazine, with its beautiful coloured plates of garden plants, is still appearing, after 160 years, is a tribute to his far-sighted estimate of horticultural and botanical needs.

In 1777, on giving up his post at Chelsea, Curtis began to move his garden from Bermondsey to Lambeth, "very near the Magdalen Hospital, St. Georges Fields, in the road from the said Hospital to Westminster Bridge Turnpike, through Lambeth Marsh Village". Here his "London Botanic Garden" was opened on January 1, 1779. Curtis's two chief patrons were Daines Barrington and Thomas White, correspondent and brother, respectively, of Gilbert White of Selborne, and there were numerous subscribers of one and two guineas. Curtis remained at Lambeth until 1789, when, driven desperate by the effect of the London atmosphere on his plants, he again moved his Garden, to a site now occupied by the Brompton Hospital for Consumption, Fulham Road. After ten further years of fruitful botanical and entomological work he died at his home near the Gardens on July 7, 1799.

Curtis's main publications, apart from the "Flora Londinensis", the *Botanical Magazine* and his two early entomological works, were "Linnaeus's System of Botany" (1777), "A Short History of the Brown-tailed Moth" (1782), and "Practical Observations on the British Grasses", which ran to several editions. Reading Mr. W. Hugh Curtis's admirable biography, however, one realizes that Curtis's influence on contemporary botany was due not only to his publications but even more, perhaps, to his friendships and correspondence with the leading botanists of the time, and to the establishment of his Garden as a rallying point for botanical endeavour throughout the country. Influence of this kind, however, though powerful at the time, becomes obscured with the passing of the years, and to-day Curtis's memory is kept green primarily by the nearly ten thousand plates and descriptions of the *Botanical Magazine*, and the two vast 'elephant folios' of "Flora Londinensis".

J. S. L. Gilmour.

Curtis as Naturalist and Humanist

William Curtis placed the following inscription on the title-page of the second volume of his "Flora Londinensis"—"With wise intent the hand of Nature on peculiar minds imprints a different bias, and to each decrees its province in the common toil". How true that remark is will be evident if we compare him with some of those other strongly individual eighteenth century naturalists—Linnaeus, to whom, from boyhood until old age, systematy was the very breath of life, and whose greatness was proved in that hard task; Peter Collinson, that benign figure of a man, introducing new plants into English gardens from the American colonies and elsewhere, as well as several new correspondents to Linnaeus; John Ellis, the discoverer, a man of keen eye and alert mind, who nevertheless left much of the actual work of classification to others; Daniel Solander, who, although Linnaeus's representative in England, was allowed by Sir Joseph Banks to publish so little; the two Martyns, with their solid classical learning; Gilbert White, who made good literature out of natural history and a beautiful Hampshire village; and many others who in varying degrees contributed to the progress of natural history in England during the eighteenth century.

Curtis became what he was born to become—a practical naturalist. His biographers mention the profound early influence of a local ostler, Thomas Legg, who was well read in the herbals of Gerard and Parkinson and could name most of the wild flowers around Alton. This was indeed the determining influence in Curtis's life, and one which lasted until he died at the comparatively early age of fifty-three. In that influence also is his link with the past, for just as the herbalists were bent on identifying living plants with those described or pictured in earlier herbals, so Curtis was fired with the ambition to describe and *picture* all the plants and animals of Great Britain.

Among the several biographies of Curtis, culminating with the excellent one by Mr. W. Hugh Curtis, "William Curtis, 1746–1799, Fellow of the Linnean Society, Botanist and Entomologist", published as recently as 1941, that by Samuel Goodenough in the *Gentleman's Magazine* for 1799 is surely the one in which we can see Curtis's personality most clearly; especially if we include the interesting extracts from Goodenough's letters to Curtis, to be found in Mr. Hugh Curtis's book. For twenty-three years, during the greater part of which Goodenough was headmaster of a school at Ealing, he knew Curtis intimately. In the year of Curtis's death, Goodenough became Canon of Windsor, and in later years, Bishop of Carlisle. He was a very good classical scholar, and as one of the three founders of the Linnean Society of London had a great influence on its early years. In many ways he was exceptional—a Hercules of a man well over six feet in height, of great breadth of mind and with much downrightness of expression; a man of uncommon common sense combined with a deep sense of religion and with a very high respect for principles. Although he became well known as a botanical author, botany and entomology were only relaxations; his real life-work lay elsewhere. There must have been something extraordinarily fine about William Curtis for him to have earned and kept that friendship.

Goodenough's biography of Curtis is dated August 4, 1799, nearly a month after Curtis's death on

July 7, and was entitled "Some Biographical Anecdotes of the late Mr. William Curtis" by the editor of the *Gentleman's Magazine*. He had access to an autobiography of Curtis, since he quotes from it. He may have obtained it from Dr. John Sims, F.R.S., with whom it is known Curtis left some such memoir. Needless to say, this document, at present lost, would be of much interest to-day; but perhaps it may have been destroyed by the 'pious' hand of someone who wanted to hush up any expression of the resentment felt by Curtis when "English Botany" was begun by Sowerby and Smith in 1790. Goodenough expressed regret that Curtis did not receive a "polished education", the lack of which he avers leads to the mind being unable "to fix itself; conscious of great and various powers, it runs from subject to subject"; though he recognized that this was not to be imputed to Curtis as a fault, but to his family's circumstances. His appreciation of Curtis's personal character is, however, unreserved: "In short, Mr. Curtis was an honest, laborious, worthy man, gentle, humane, kind to every body, a pleasant companion, a good master, and a steady friend. His Flora Londinensis will be a *monumentum aere perennius*. The size, the accuracy of the work, the masterly exemplification of dissection of flowers, will do much for the establishment of the Linnæan system as any work which ever appeared. . . ." Again, "there never was a pleasanter companion than Mr. Curtis: he abounded in innocent mirth; and good-humour ever floating uppermost gave a pleasant cast to every thing he said or did". If the passage from the autobiography is added—"I have no pretensions to be considered as a man of letters, or of great mental powers, I know myself and my imperfections. A consciousness of my inabilities makes me diffident, and produces in me a shyness, which some have been ready to construe into pride", it must be admitted that Curtis was indeed a worthy representative of the best type of eighteenth century naturalist; and although Goodenough may have been right in his views on education, it seems nevertheless true that had Curtis received a "polished education", the world might not have had either "Flora Londinensis" or the *Botanical Magazine*.

As a practical man, Curtis used the means available to begin to realize his dream of a complete Flora and Fauna of Great Britain; and about the year 1777 he decided to give up taking an active part in his business as an apothecary and to concentrate his energies on that task. He gave up also his post as demonstrator at the Chelsea Physic Garden, which he had held since 1772. His small garden at Grange Road, Bermondsey, becoming inadequate for his scheme, he took a more extensive piece of ground in Lambeth Marsh (its position to-day would be just north-east of Waterloo Station), where he proceeded to open the London Botanic Garden* for growing the wild flowers which were to be figured in the "Flora Londinensis" and on which he was to lecture to the subscribers who supported his garden. In 1789 he transferred the Garden to Brompton, partly because the smoke of London spoiled his plants and partly because a new lease of the land involved too heavy a rent.

William Curtis accomplished much in his comparatively short life, in spite of his lack of a "polished education". Without doubt his early enthusiasm must have weakened when financial difficulties began to slow up the publication of "Flora Londinensis". Goodenough attributed the financial failure of the "Flora Londinensis" to the slowness with which Curtis issued the parts; and even blamed the French Revolution! In spite of the sale of each part not rising above three hundred copies, Curtis refused to withdraw from his original proposal that each part should be sold at 2*s*. 6*d*. plain; 5*s*. coloured; and 7*s*. 6*d*. coloured with extra care (probably by William Graves, who out of about thirty plate-colourists employed by Curtis was the best colourist; and who continued to work until he was seventy-three years of age, when his colouring is recorded to have been as good as ever). It is characteristic of Curtis that he was ready to sacrifice much to carry out his scheme for picturing life-size every British plant; but in spite of generous help from friends the scheme was too big for one man to accomplish. By good fortune, his founding of the *Botanical Magazine*, with its wider horticultural appeal, proved a success from the start; and his name will always be remembered as its founder.

Although Curtis did not make any outstanding discoveries in natural history, being blessed with very keen eyesight he did make some. These Goodenough mentions in part. What is of greater importance is that he, as a benevolent average man, aroused in many thousands of his fellow-countrymen a taste for botanical and horticultural studies, and so performed a service of national importance. Indeed, as one whose constant aim was to help his fellows, as his miscellaneous publications most clearly show, he merits to be classed not only as a naturalist but as a humanist also.

A genus of Cornaceæ, *Curtisia* Aiton, was founded in 1789 in his honour. This is the Assagay tree of South Africa; perhaps not a very happy choice for honouring one of Quaker family. Two good contemporary portraits of Curtis exist—the oil painting by Wright in the Royal Horticultural Society's collection and a miniature by Angelica Kauffmann, R.A. Both are reproduced in Mr. Hugh Curtis's book. A third painting, in oils, said to be by Zoffany, was sold in 1923 and is now in an art gallery in India.

S. Savage.

Chronica Botanica, **9**, plate 9 (1945), reproduces James Sowerby's water-colour drawing of the Garden, painted before 1787.

NEWS and VIEWS

New Year Honours List

The New Year honours list, and another to be published on January 9, are much longer than the usual lists, so as to provide recognition for war services, military and civil, in the many theatres of activity during the Second World War. It includes the following names of scientific men and others associated with scientific work:

G.B.E.: Sir Edward Appleton, secretary of the Department of Scientific and Industrial Research.

Companion of Honour: Prof. A. V. Hill, a secretary of the Royal Society, for scientific services.

K.C.B.: Sir Donald Vandepeer, permanent secretary of the Ministry of Agriculture and Fisheries.

K.C.V.O.: Sir Stewart Duke-Elder.

K.B.E.: Sir John Renwick, lately controller of communications, Air Ministry, and of communications equipment, Ministry of Aircraft Production.

Knights: Mr. W. A. Akers, director of atomic bomb research, Department of Scientific and Industrial Research; Mr. D. C. Bailey, acting super-

intendent, Experimental Bridging Establishment, Ministry of Supply; Dr. C. Forster-Cooper, director of the British Museum (Natural History); Prof. C. D. Ellis, Wheatstone professor of physics at King's College, University of London, scientific adviser to the Army Council; Dr. P. G. Fildes, director of chemical bacteriology, Medical Research Council; Dr. C. F. Goodeve, deputy controller, Research and Development, Admiralty; Prof. I. M. Heilbron, professor of organic chemistry in the Imperial College of Science and Technology, London, lately scientific adviser, Ministry of Production; Mr. B. Lockspeiser, director of scientific research, Ministry of Aircraft Production; Dr. E. J. Salisbury, director of the Royal Botanic Gardens, Kew; Dr. A. M. Carr-Saunders, director of the London School of Economics; Mr. H. R. Stewart, vice-chairman of the Imperial Council of Agricultural Research, India; Dr. H. A. Tempany, agricultural adviser to Secretary of State for the Colonies; Mr. F. Ware, director of animal husbandry, United Provinces, India.

C.B.: Prof. S. Zuckerman, professor of anatomy in the University of Birmingham, scientific director, R.A.F. Bombing Analysis Unit, for distinguished service; Mr. R. V. Jones, assistant director of intelligence (science), Air Ministry, for distinguished service.

C.M.G.: Prof. H. J. Channon, professor of chemistry, University of Liverpool, a member of the Advisory Committee on Education in the Colonies, for services to education; Prof. A. K. Macbeth, Angus professor of chemistry, University of Adelaide, for public services; Mr. J. Saint, director of agriculture, Barbados; Mr. E. Marsden, secretary of the Department of Scientific and Industrial Research, New Zealand.

C.I.E.: Mr. R. H. Hill, director of agriculture, C.P. and Berar; Sardar Gandasing Cheema, principal of the Agricultural College, Poona; Ram Chandra Srivastava, director of the Imperial Institute of Sugar Technology, Cawnpore; Mr. H. P. Smith, senior conservator of forests, Assam; Mr. P. H. Carpenter, director of the Scientific Department, Indian Tea Association, Assam.

C.B.E.: Prof. A. W. Ashby, lately professor of agricultural economics, University College, Aberystwyth; Mr. R. Corless, assistant director of the Meteorological Office, Air Ministry; Mr. W. C. M. Couch, deputy director of electrical engineering, Admiralty; Prof. J. Cruickshank, professor of bacteriology, University of Aberdeen, for services to civil defence; Dr. P. Dunsheath, chief engineer and director, W. T. Henley's Telegraph Works Co., Ltd.; Mr. C. W. Goyder, chief engineer, All-India Radio; Prof. J. Gray, professor of zoology, University of Cambridge; Mr. G. R. D. Hogg, assistant secretary, Department of Scientific and Industrial Research; Prof. H. D. Kay, director, National Institute for Research in Dairying, University of Reading; Dr. T. Moran, director of research and deputy scientific adviser, Ministry of Food; Prof. R. E. Peierls, professor of applied mathematics, University of Birmingham, scientific consultant on atomic bomb research, Department of Scientific and Industrial Research; Mr. A. J. Philpot, director of research and secretary, British Scientific Instrument Research Association; Mr. J. D. Pratt, director and secretary, Association of British Chemical Manufacturers; Mr. W. G. Radley, controller of research, Engineer-in-Chief's Office, G.P.O.; Prof. F. E. Simon, professor of thermodynamics, University of Oxford; Mr. J. R. N. Stone, lately chief statistical assistant, Offices of the Cabinet and Ministry of Defence; Mr. P. C. Vellacott, lately head of the Political and Psychological Warfare Department, Mediterranean Theatre; Dr. J. A. Scott-Watson, chief education officer, Ministry of Agriculture and Fisheries.

British Cast Iron Research Association: Dr. Harold Hartley

Dr. Harold Hartley, technical director and managing director of Radiation, Ltd., has been elected president of the British Cast Iron Research Association. Dr. Hartley entered the University of Manchester in 1904, where he studied under Profs. Dixon, Perkin and Bone. Afterwards he travelled in Norway and Canada, collating data on the cost of power production for electro-chemical industries. On returning to Britain in 1909 he was elected to a gas research fellowship at the University of Leeds. In 1912 he was appointed to the staff of the Richmond Gas Stove Co. at Warrington to build up a research section. He was especially concerned in the development of furnaces both for non-ferrous metal melting and for heat-treatment processes generally. With the formation of the Radiation Group in 1919, Dr. Hartley was appointed chief chemist and head of the Research Department. In 1925 the new central research laboratories were inaugurated in London and there followed a period of activity which has led to marked developments in gas- and coke-burning apparatus. In 1937 additional new and enlarged laboratories were opened in Birmingham, and in 1939 the central research organisation was transferred to the Midlands. Shortly afterwards Dr. Hartley was appointed to the board of Radiation, Ltd., as technical director, and he became a joint managing director in 1944. Dr. Hartley has been associated for many years with the British Cast Iron Research Association, becoming chairman of the Research Committee in 1936 and chairman of the Council in 1938.

Atomic Energy and the Freedom of Science

At a meeting of the Physical Science Section of the Royal Netherlands Academy of Sciences held on October 27, the following resolution was carried unanimously and has been forwarded to the Netherlands Government:

"The Royal Netherlands Academy of Sciences, Physical Science Section, wishes to state,

"1. that as a result of scientific research, intra-atomic energy has been made available to human society as a new source of energy;

"2. that, consequently, far-reaching possibilities offer themselves for a better world economy;

"3. that, however, these discoveries have first of all been developed into the atomic bomb, the implement of which is an abhorrent destructive power;

"4. that men of science, which have created these possibilities, are well aware of their responsibilities in this respect;

"5. that it is unacceptable with regard to the furthering of science and with regard to the entailing development of social welfare and social hygiene, that results of scientific research be kept secret.

"The Academy therefore appeal to the sense of responsibility of Governments and of scientific institutions, to collaborate in solely making available the fruits of scientific research, to the benefit of civilization, and preventing them from becoming a threat.

"The Academy herewith express their desire that the

world of science shall be adequately and permanently represented in the discussions on these matters.

"The Academy request all scientific institutions in other countries to support this motion, so that the whole world of science may express their desire to be entrusted with their full share of responsibility for the results of scientific research, and their desire to offer their best services in the application of these results for the benefit of mankind."

National Physical Laboratory Appointments

MR. F. H. ROLT has been selected for the appointment of superintendent of the Metrology Division of the National Physical Laboratory, with effect from April 1, 1946, on the retirement from that post of Mr. J. E. Sears. Mr. Rolt has been a member of the staff of the National Physical Laboratory since 1912, but during the War his services have been lent to the Ministry of Supply, where he has held the post of director of jigs, tools and gauges.

Mr. A. Fage has been appointed superintendent of the Aerodynamics Division of the National Physical Laboratory to fill the vacancy caused by the resignation of Mr. E. F. Relf, who is taking up the post of principal of the College of Aeronautics. Mr. Fage has been a member of the staff of the National Physical Laboratory since 1914.

University of London Appointments

MR. C. W. DANNATT, reader in metallurgy since 1937 and since 1940 acting head of the Metallurgy Department at the Royal School of Mines, has been appointed to the University chair of metallurgy tenable at the Imperial College of Science and Technology.

The title of professor of applied physiology in the University has been conferred on Dr. G. P. Crowden in respect of the post now held by him at the London School of Hygiene and Tropical Medicine.

Dr. J. H. Birkinshaw, since 1938 senior lecturer in the Department of Biochemistry at the London School of Hygiene and Tropical Medicine, has been appointed to the University readership in biochemistry tenable at the School.

Dr. Aubrey Lewis has been appointed to the University chair of psychiatry tenable at the Maudsley Hospital, where he has been clinical director since 1936.

Catalogue of Scientific Instruments and Apparatus

THE annual Exhibition of Scientific Instruments and Apparatus organised by the Physical Society for many years before the War was always an important occasion for the physical sciences, and the very full catalogue prepared in connexion with the Exhibition served as a guide and record of much value. It is an achievement on the part of the Society, and of the officers particularly concerned, that the first post-war issue of the Exhibition catalogue has been issued promptly, and in its well-known style. The Trade Section occupies 232 pages, and apparatus being shown for the first time is marked by asterisks; the Research and Educational Section occupies 45 pages. There are alphabetical lists of the exhibitors in these two sections, and a subject index of the whole. It will quickly take its place, with preceding volumes, as a reference work; and it is of special interest as illustrating many of the developments of the war years. The catalogue is published by the Physical Society, 1 Lowther Gardens, Exhibition Road, London, S.W.7, price 2*s.* net to non-members (2*s.* 6*d.* post paid).

Announcements

MR. D. N. LOWE has been appointed secretary of the British Association, in succession to Dr. O. J. R. Howarth. Dr. Howarth was due to retire in 1942 but will remain in office until the next annual meeting. Mr. Lowe became assistant secretary before the War, and is at present serving with the Ministry of Production.

DR. J. RAMSBOTTOM, keeper of botany in the British Museum (Natural History), has been elected president of the British Mycological Society for 1946, in which year the Society celebrates the fiftieth anniversary of its foundation.

THE following appointments, transfers and promotions in the Colonial Service have recently been made: G. Wrigley, to be agricultural officer, Uganda; C. G. L. Beveridge, to be veterinary officer, Uganda; M. Park (plant pathologist, Ceylon), to be deputy director of agriculture, Ceylon; R. S. Pelly (assistant conservator of forests, Sierra Leone), to be senior assistant conservator of forests, Sierra Leone; W. G. Emerson (deputy director of veterinary services, Kenya), to be director of veterinary services, Kenya.

A SERIES of thirteen lectures on "Recent Advances in Dairy Science", under the auspices of Chelsea Polytechnic, will be delivered on Tuesdays, beginning on January 15, at the Central Laboratories, Express Dairy Co., Ltd., 133 Euston Road, London, N.W.1. The inaugural address will be given by Prof. H. D. Kay, director of the National Institute for Research in Dairying, who will speak on "The Future of Dairy Research". Succeeding lectures will be given by specialists from the academic side and from industry. Applications to attend the course should be sent to the Principal, Chelsea Polytechnic, Manresa Road, S.W.3 (fee for the course, £1; individual lectures, 2*s.* 6*d.*).

A CONFERENCE on muscular contraction, of special interest to rheologists, has been arranged for February 15 and 16, under the joint auspices of the Section of Biology and the Section of Physics and Chemistry of the New York Academy of Sciences. Session 1 is to deal with dynamics of muscular contraction (Drs. A. Sandow, R. Ramsey and A. Gibson); in session 2 the speakers (Drs. F. Schmitt, E. Fischer and E. Guth) plan to give an account of ultra-structure by electron microscope and X-rays, with birefringence, including the relation between high elasticity of rubber and of muscle. Session 3 comprises an integrated account of recovery chemical reaction (Drs. O. Meyerhof and S. Ochoa), and intra-cellular actions and muscle action (Dr. H. Steinwach). The subject of mechano-chemical coupling is chosen for session 4, and the speakers are Drs. D. Brown, S. Shen and A. Sandow.

METROPOLITAN-VICKERS Electrical Co., Ltd., have acquired a substantial interest in the old-established business of Newton and Wright, Ltd., the well-known manufacturers of X-ray apparatus and optical equipment. Newton and Wright will remain a separate entity, but there will be the closest co-operation between the two Companies. The present directors of Newton and Wright, Ltd., will remain on the board; Mr. R. S. Wright is relinquishing his position as managing director of Newton and Wright, Ltd., after a connexion of fifty-four years, but retains that of chairman of the Company. Mr. H. A. Quinton, who has been associated with the Company for thirty-two years, becomes general manager.

LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. No notice is taken of anonymous communications.

A New Method for the Separation of the Amylose and Amylopectin Components of Starch

A NUMBER of methods are available for the separation of the unbranched (amylose) and branched (amylopectin) components of starch. Of these methods, that of T. Schoch[1] has been generally useful but presents certain disadvantages as a routine method inasmuch as it consists in a relatively high-temperature treatment, under pressure, of starch paste with butanol and *iso*amyl alcohol, and this treatment is known to cause some hydrolytic degradation of starch. The amylose component forms a complex with butanol which is insoluble in water, whereas amylopectin either does not form such a complex or, more probably, forms a complex which is soluble in water.

We have had in use for more than a year a method which avoids most of the difficulties of the Schoch method and attains a sharper separation of the starch components. The principle of the new method is the same, namely, the precipitation of amylose as a water-insoluble complex. The precipitant we use is, however, thymol, and the operation is carried out at the temperature of the laboratory.

The starch is dispersed in water by being creamed with cold water and then poured into boiling water with vigorous mechanical stirring. The stirring is continued at the boiling temperature for half an hour; sodium chloride is added to make a 0·1 per cent solution and thereafter the solution is cooled rapidly to room temperature. The optimum concentration of the starch is 1 per cent, but the following procedure has been successfully carried out with 3 per cent solutions. Powdered thymol is now stirred into the liquid in such amount as to ensure complete saturation (0·13 per cent). In a short time the thymol-amylose complex begins to separate and its precipitation is complete in a minimum period of forty-eight hours. The precipitate is removed at the centrifuge, is washed rapidly with (i) water saturated with thymol, (ii) absolute alcohol, and (iii) ether. These operations must be carried out as rapidly as possible and the product dried in a vacuum, otherwise a water-insoluble amylose is obtained.

The amylopectin component is obtained from the mother liquor when the latter is concentrated to a quarter of its bulk at 60° C. and treated with one volume of methylated spirits. The precipitate is washed and dried with alcohol and ether.

As a criterion of purity of the separated components, the blue value, that is, the intensity of the blue colour of the iodine complex prepared under the standard conditions prescribed by McCready and Hassid[2], was measured by means of a Spekker absorptiometer. The yield of amylose precipitated by thymol from potato starch varied between 20 and 22 per cent of the weight of starch, and this material showed blue values between 0·9 and 1·2. Occasionally a higher yield of amylose (up to 25 per cent) was obtained; but such an amylose preparation showed a blue value less than 0·9. The blue value is usually raised if the amylose is dissolved in water and re-precipitated with thymol. We have some reason to believe, however, that more than one amylose type may exist in potato. It is, for example, usually not possible, by reprecipitation, to convert an amylose with a blue value of 0·9 into one with a blue value of 1·2.

The iodine complex of thymol-amylopectin, which is purple in colour, shows a blue value varying between 0·18 and 0·25, most specimens showing a value of 0·22. The corresponding blue values for specimens of potato amylose and amylopectin separated by the butanol method were 1·05 and 0·18 respectively, and an average sample of whole potato starch showed a blue value of 0·41.

With a view to the investigation of the mechanism of amylose-precipitation, we have examined the efficacy as precipitants of a very wide range of organic compounds. Of these, cyclic alcohols (for example, cyclohexanol) and terpene derivatives (such as menthol, borneol or terpin hydrate) are sufficiently active to be worthy of further study. In particular, we have found a combination of thymol and cyclohexanol (or methyl cyclohexanol) to be especially useful in the preparation of pure amylopectin (that is, amylopectins with very low blue values). The amylose so separated contains a higher proportion of amylopectin than does that obtained when thymol is used alone, but amylopectin specimens have been prepared, in good yield (60–70 per cent of the starch), with blue values so low as 0·02. Details of this method of preparing amylopectin will be published later.

W. N. HAWORTH.
S. PEAT.
P. E. SAGROTT.

A. E. Hills Laboratories,
University, Birmingham.
Sept. 11.

[1] Schoch, *J. Amer. Chem. Soc.*, **64**, 2957 (1942).
[2] Hassid and McCready, *J. Amer. Chem. Soc.*, **65**, 1154 (1943).

Lattice Defects in Silver Chloride Crystals

SILVER chloride crystals, with dimensions up to about ½ cm., were obtained by recrystallization of material solidified from the molten state. Fig. 1 shows some recrystallized plates after etching with a dilute solution of sodium thiosulphate.

Laue photographs of these crystals show diffuse bands and spots, the bands being of similar character to those observed recently by Arlman and Kronig[1] (cf. also van Reyen[2]) with tin crystals (Fig. 2).

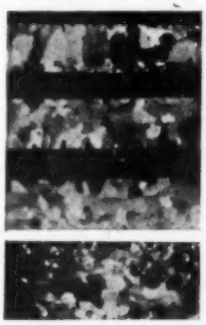


Fig. 1. *a*, *b*, *c*: Rolled and recrystallized plates of silver chloride with large crystals, after etching with sodium thiosulphate (1 per cent solution). Approx. nat. size.
d: Silver chloride plates with large crystals, 'etched' by irradiation with light from a mercury arc lamp. From a determination of the lattice orientation by means of X-rays, it follows that the 'etched' planes are parallel to the cube planes of the crystal lattice.

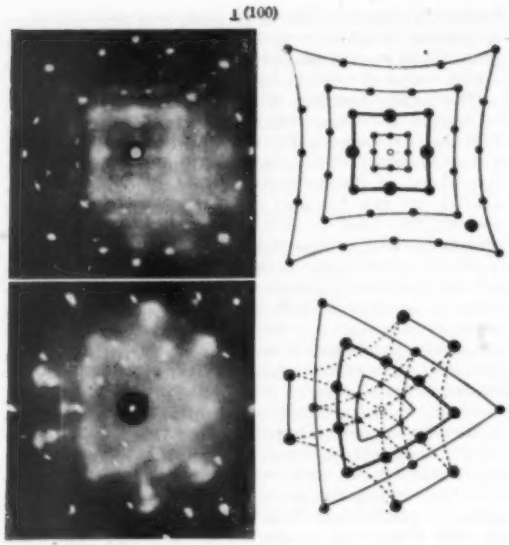


Fig. 2. Laue photographs of a silver chloride crystal, obtained by recrystallization. Incident beam ⊥ (100) and ⊥ (111). Molybdenum radiation. The diffuse bands and spots are due to the molybdenum characteristic radiation.

According to these authors, the bands point to the presence of definite lattice defects in the tin crystals, consisting of a displacement of entire rows of tin atoms along their own direction parallel to the *a*-axes of the elementary cell. (From the available literature[3], we have the impression that this conception shows an analogy with those put forward by Sir William Bragg regarding the cause of 'extra' reflexions in various crystals.) So far as we can see, the appearance of the *bands* in the silver chloride crystals is also in agreement with the assumption that in these crystals similar lattice defects are present parallel to the cubic axes and planes (the diffuse *spots* being probably due to the thermal agitation of the atoms of the lattice).

Our conclusion seems to be confirmed by the following observation. After irradiation with a mercury-arc lamp, the crystals turn violet and show a reflexion of incident light, similar in appearance to the reflexion effect, observed after etching the crystals with sodium thiosulphate (Fig. 1 *d*). From a determination of the crystal orientations by means of X-rays, it follows that in both cases the 'etched planes' are parallel to the cubic planes. This seems to indicate that the photolytically formed silver is in some way deposited at, and 'parallel' to, the lattice deviations assumed to be present in the crystals.

It must be remarked that up to the present Laue photographs of silver chloride crystals were taken at room temperature only. The colouring effect, however, was also observed with crystals cooled by liquid air. For particulars we must refer to a forthcoming paper in *Physica*.

W. G. Burgers.
Tan Koen Hiok.

Laboratory for Physical Chemistry,
Technical University, Delft. Aug. 22.

[1] Arlman, J. J., and Kronig, R., *Physica*, **10**, 795 (1943).
[2] van Reyen, L. L., *Physica*, **11**, 114 (1944).
[3] Lonsdale, K., *Proc. Phys. Soc.*, **54**, 314 (1942); see p. 325.

Changes in Polycrystalline Barium-Strontium Titanate at its Transition Temperature

The changes in a single crystal of potassium dihydrogen phosphate passing through its transition point have been described in a recent letter by Ubbelohde and Woodward[1]. Changes of a rather similar character occur in barium-strontium titanate, as I have been able to observe. The material examined (a solid solution of $BaTiO_3$ and $SrTiO_3$ in a molar ratio of about 7 : 1) has, at room temperature, a tetragonal perovskite-type structure like barium titanate[2] with an axial ratio $c/a = 1{\cdot}0072$, and changes at about 80° C. to an ideal cubic perovskite type. The change from cubic to tetragonal involves a simple uniform extension of the unit cell along one cube axis, which becomes the *c*-axis. There are three ways of selecting this axis for a given cubic crystal, and therefore three aspects (with *c*-axes mutually at right-angles) in which a tetragonal structure may be derived from the cubic with very little actual rearrangement of the atoms.

The question is, does a single cubic crystal invert to a single tetragonal crystal, or to a 'hybrid' or twin including all three tetragonal aspects, or does the texture change altogether so that the identity of the original crystals is lost?

A piece of polycrystalline material, broken from a sintered mass, was investigated by the powder method; the specimen was kept in a fixed position relative to the X-ray beam throughout the experiment, and back-reflexions were recorded on a flat film about 9·5 cm. away. A small oven around the specimen could be used to hold its temperature steady above the transition point.

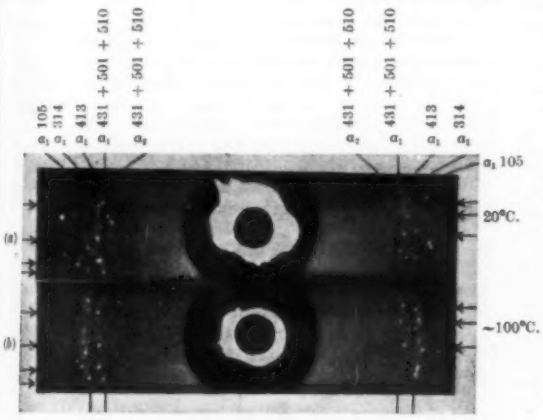
With copper $K\alpha$ radiation, the 431 and 510 (overlapping) reflexions from the cubic crystal are conveniently placed with a θ-value of about 80°, the α-doublet separation being about 1°. The tetragonal structure gives a group of lines in the same region, 105, 314, 413, 431+501+510 (the last three overlapping). Of these, $412\alpha_1$ coincides in position with the cubic α_1, $431\alpha_1$ and $501\alpha_1$ with the cubic α_2. This coincidence depends on the axial ratio and proved very important in allowing the results to be interpreted. (The tetragonal α_2 lines may be neglected, since they either overlap with other α_1 lines or fall outside the region in which we are interested.)

With only a small area of the specimen illuminated, the photographs consisted of discrete spots, as shown in the accompanying reproduction. The following observations were noted: (1) The spots on the cubic photograph were very sharp; those on the tetragonal photographs were rather more blurred, but still completely distinct. (2) The cubic photograph was accurately reproducible after cooling and reheating; the tetragonal photograph was nearly though not perfectly reproducible, even under different cooling conditions. (3) Most of the spots on the cubic α_1 line and all spots on the cubic α_2 line were matched by corresponding spots on the tetragonal 413 or 431 line respectively. (This can be seen by comparison of the two photographs reproduced, but is more obvious if they can be superposed.)

These observations lead to certain interesting conclusions. (1) The cubic material is practically strain-free, as shown by the sharp spots. (2) The texture of the tetragonal material is determined by that of the cubic, and only to a very minor degree

by external conditions during cooling. (3) In general, each single cubic crystal inverts to a 'hybrid' or twin involving all three possible tetragonal aspects.

To prove this point, we note that a plane of the set {431} in the cubic structure may become one of {431}, {413}, or {314} in the tetragonal, and all three will occur with equal probability; but it will only reflect X-rays if its spacing continues to satisfy the Bragg law for the original angle of incidence of the beam, that is, if it has the same θ-value as the original cubic. Thus we only expect tetragonal $413\alpha_1$ reflexions on inversion from cubic crystals originally reflecting α_1, and tetragonal $431\alpha_1$ on inversion from cubic crystals originally reflecting α_2. But since nearly all the cubic spots (and not only one third of them) are matched by tetragonal spots of the same θ-value, it means that nearly all the cubic crystals give tetragonal crystals of this particular aspect, and therefore presumably of all three aspects. The 510 reflexions are weaker, but similar arguments apply. Here, however, none of the tetragonal spacings is identical with the cubic, and thus a cubic crystal giving an α_1 spot cannot do so when tetragonal. Since one cannot distinguish cubic 510 and 413 spots on a powder photograph, this will account for the few cases in which a cubic α_1 spot has not its tetragonal 413 counterpart. On the other hand, a cubic 501 α_2 reflexion will always be matched by



PHOTOGRAPHS FROM SAME PART OF POLYCRYSTALLINE MATERIAL, (*a*) BELOW, (*b*) ABOVE TRANSITION TEMPERATURE.

Note corresponding spots on the α_2 line in (*b*) and the 431 + 501 + 510 α_1 line in (*a*), at heights marked by arrows on either side; also two spots on the α_1 line at the lower left-hand side of (*b*) which correspond to two on $413\alpha_1$ in (*a*).

a tetragonal $501\alpha_1$ at the same angle, in accordance with observation.

It is not possible to say from this work how the crystals are arranged in the hybrid, but it is likely to be some form of close twinning, comparable with that observed in the mineral perovskite. The sizes of the tetragonal regions are not so small as to lead to appreciable diffraction broadening, and must therefore be upwards of 10^{-6} cm. diameter. The crystals as observed under the microscope (they may be single or twinned) were mostly about $5–10 \times 10^{-4}$ cm., with a few larger individuals up to 30×10^{-4} cm.

Attempts to study the same effect in pure barium titanate failed because the material available did not give discrete spots free from background, and because its axial ratio did not lead to the same exact coincidence of cubic and tetragonal lines.

I wish to thank Mr. J. A. M. van Moll and the directors of Philips Lamps Limited for permission to publish this work.

HELEN D. MEGAW.
Material Research Laboratory,
(Philips Lamps, Ltd.),
New Road, Mitcham Junction,
Surrey.
Aug. 23.

[1] Ubbelohde, A. R., and Woodward, I., *Nature*, **156**, 20 (1945).
[2] Megaw, H. D., *Nature*, **155**, 484 (1945).

Time Factors in the Breaking of Toughened Glass

RECENTLY there has been much interest in the relationship between rates of stressing and strength properties of glass, and several hypotheses and relations have been put forward in connexion with the quantitative phenomena concerned[1–5]. In one of these[1], it is suggested that the decrease of the breaking stress with increase in duration of loading should be slower with toughened glass than with sheet. However, the same conclusion follows from the quantitative formulation[6] of the commonly accepted view of the nature of

toughened glass, namely, bending strength of toughened glass = bending strength of sheet glass + increase due to toughening process $= f(t) + K$.

If only the first of these quantities is taken to be time-sensitive, it follows that the variation in the bending strength of toughened glass with time should be absolutely, but not relatively, the same as with sheet glass.

To test this point, some experiments were made on the breaking of 6 in. × 6 in. squares of toughened glass under a central force applied by a 1·7/16 in. ball bearing and the bending strength of the square was calculated according to the equations of Timoshenko, as described elsewhere[7]. The glass specimens were simply supported by a stout steel frame 13·3 cm. square. The lever arrangements used gave a stress magnification of 14 : 1 with the toughened glass and 6 : 1 with the sheet glass. The stress was applied with a spring balance in the short-time experiments and by loading the scale pan in 1 kgm. steps in the slow experiments. This difference in continuous and discontinuous loading was corrected by subtracting ½ kgm. from the average load in the slow discontinuous experiments (that is, 7 and 3 kgm. respectively taken from the average central force for the slowest two experiments in each case). It is likely that the most important source of error lay in the fact that it was difficult to apply the high loads required in the case of toughened glass without some vibration which, although it did not cause appreciable fluctuation in the force recorded by the spring balance, could have led to momentarily increased stresses and hence to possible low values of the breaking strength at the two shorter times. This error was more serious with toughened glass *A* than *B*.

The results of these experiments are given below, together with statistical factors derived from the best estimate of the standard deviation (*s*) as laid down by Evans[8].

Average thickness	Average time	Average force	Bending strength $B \pm 2s/\sqrt{N}$	N = number of tests	Coefficient of variation $V = \frac{s}{B}$
cm.	sec.	kgm.	kgm./cm.²		per cent
Sheet Glass					
0·405	2160	62·4	730 ± 70	28	25
0·406	180	79·8	930 ± 77	30	23
0·407	23	84·6	990 ± 70	30	19
0·406	1·8	96·6	1140 ± 100	30	25
Absolute difference in bending strength due to time factor 410 kgm./cm.²					
Toughened Glass A.					
0·524	4620	331	2250 ± 110	19	10·6
0·523	312	343	2330 ± 120	20	11·9
0·522	32	342	2320 ± 90	20	9·0
0·524	2·8	370	2510 ± 170	20	14·8
Absolute difference in bending strength due to time factor 260 kgm./cm.²					
Toughened Glass B.					
0·467	2260	239	2070 ± 92	36	13·4
0·462	201	246	2180 ± 93	37	12·9
0·464	26	257	2260 ± 91	36	12·1
0·464	2·2	290	2550 ± 107	44	13·9
Absolute difference in bending strength due to time factor 480 kgm./cm.²					

After obtaining the results with toughened glass *A*, it was apparent that the total differences obtained between the highest and lowest values could have come about by chance on about one occasion in fifty, and the experiments were therefore repeated with larger numbers.

Taken together, the figures show: (1) The absolute value of the time factor in the bending strength of toughened glass is of the same order as for sheet glass. (2) The coefficient of variation of bending strength of this commercial toughened glass was lower than that for sheet glass.

As a consequence of these two properties, it would follow that toughened glass is a more reliable material than sheet glass so far as steady bending stresses are concerned.

If the point of view put forward here is correct, the bending strength of ordinary toughened glass cannot throw much light on rival opinions as to the character of the time factor, since the toughening process merely makes it more difficult to apply a stress to critical surface flaws, and the first stages of the real breaking process are the same for each of the two types of glass. However, some evidence has been brought forward by Littleton and Preston[9] that internal rupture takes place in the case of certain very highly tempered glasses. Where such a mode of rupture can be shown to exist, evidence distinguishing between the contamination theory put forward by Orowan and the other proposals may be obtained, but my experience suggests that such experiments may be difficult to perform and not easy to interpret.

R. N. Haward.

Colmore Adhesives, Ltd.,
Gateshead-on-Tyne, 11.

[1] Orowan, E., *Nature*, **154**, 341 (1944).
[2] Murgatroyd, J. B., *Nature*, **154**, 57 (1944). *J. Soc. Glass Tech.*, **28**, 406 (1944).
[3] Bailey, J., *Glass Ind.*, Jan.-April (1939).
[4] Haward, R. N., *J. Soc. Glass Tech.*, **23**, 426 (1944).
[5] Preston, F. W., *Nature*, **156**, 55 (1945).
[6] Haward, R. N., *J. Soc. Glass Tech.*, **28**, 133 (1944).
[7] Haward, R. N., *J. Soc. Glass Tech.*, **28**, 5, Fig. 1 (1944). Poisson's ratio taken as 0·25.
[8] Evans, U. R., *Chem. and Ind.*, **64**, 106 (1945).
[9] Littleton, J. T., and Preston, F. W., *J. Soc. Glass Tech.*, **13**, 336 (1929).

Suspected Copper Deficiency in Cattle in Aberdeenshire

In a recent report[1] it was shown that a scouring disease which affected cattle and sheep on reclaimed swamps and peaty soils in New Zealand was due to a deficiency of copper in the pasture. Affected animals showed low levels of copper in blood and liver; the pasture contained only 2–5 p.p.m. of copper on a dry-matter basis compared with 'normal' levels of 10 p.p.m. or more, and the disease could be controlled by administration of copper to the livestock or by top-dressing the pasture with fertilizers containing copper. This 'peat scours' of New Zealand resembles the scouring disease in cattle attributed to copper deficiency on the sandy soils and reclaimed polders of Holland[2,3].

We have recently observed what appears to be a similar condition in young cattle on a small Aberdeenshire farm on land newly reclaimed from heather. Analysis of the pasture indicated that the only significant feature was its very low copper content.

Composition of pasture (dry matter basis).

Ash	P_2O_5	K_2O	CaO	MgO	Na_2O	MnO
%	%	%	%	%	%	%
5·8	0·52	1·42	0·92	0·30	0·25	0·032

Co	Ni	Mo	Fe	Cu
p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
0·12	0·57	0·62	122	2·5

One of the three affected animals which had been scouring badly showed a hæmoglobin content of 7·9 gm. per 100 ml. and a red cell count of 7·5 million per c.mm. It died before any treatment could be given. The two remaining animals, which had been taken off the 'affected' pasture, were drenched with copper and showed some improvement. Faecal worm-egg counts excluded parasitic infestation as a causative factor.

Despite the preliminary and inconclusive nature of these observations, they were thought to be of sufficient interest to justify recording, pending further investigations of this and other cases of scouring of unknown etiology in the district. So far as we are aware, the occurrence of disease in grazing livestock associated with pastures low in copper has not previously been reported in Britain.

We are indebted to the Macaulay Institute of Soil Research for the pasture analysis.

S. Jamieson.

North of Scotland College of Agriculture.

F. C. Russell.

Imperial Bureau of Animal Nutrition,
Rowett Research Institute,
Bucksburn, Aberdeenshire.

[1] Cunningham, I. J., *New Zealand J. Agric.*, **69**, 559 (1944).
[2] Brouwer, F., Frens, A. M., Reitsma, P., and Kalisvaart, C., *Landbouwk. Onderz. Rijkslandbouwproefstation, Hoorn*, No. 44 (4) C, 267 (1938).
[3] Sjollema, B., *Biochem. Z.*, **295**, 372 (1938).

Toxicity of Thiourea to Rats

Different workers have found the toxicity of thiourea to rats to be very variable[1,2,3]. Dieke and Richter[4] claim that the degree of susceptibility of rats to poisoning by thiourea can be correlated with breed and age. They also suggest that diet plays some part.

In our laboratory, well-fed experimental rats of the hooded (Rowett) strain tolerate thiourea well in doses up to 200 mgm. To determine whether a dietetic factor is responsible for the toxic effect reported by others, a large group of rats was fed an unsupplemented diet, and occasional rats died after small doses of thiourea. Pregnant and lactating animals on such diets are susceptible to very small doses. A diet of oatmeal induces maximum sensitivity to the toxic action of thiourea. Animals maintained on oatmeal for periods of four weeks or more become

extremely sensitive, so that 100 per cent mortality results from the administration of 20 mgm. of thiourea. In some cases 0·2 mgm. by intraperitoneal injection is fatal.

The pathological picture varies with the time of death after administration of the drug. Those dying within four hours show massive pulmonary œdema, but in those surviving beyond this period, the pulmonary œdema gives place to pleural effusion. Where death does not occur for twenty-four hours, the total volume of exudate may be as great as 8 ml. These changes are associated with great haemo-concentration, and the protein content of the pleural fluid is similar to that of normal plasma.

The addition of small quantities of iodide, bromide, calcium, dried thyroid or methionine to the oatmeal diet failed to protect the animals from this toxic action.

Thiouracil in doses up to 100 mgm. by mouth or by injection does not produce any toxic effects in oatmeal-fed rats. Following the administration of thiouracil, thiourea is not toxic even in large doses. Similarly, susceptible animals which survive the illness produced by very small doses of thiourea are later immune to the toxic action of large doses.

Number of rats (oatmeal diet)	Thiouracil (mgm.)	Thiourea (mgm.)	Number of deaths
6	0	1	4
7	0	20	7
12	0	100	12
6	20	20	0
6	100	100	0

The lesion produced by thiourea is probably due to a change in the pulmonary capillaries and is not a general phenomenon, as other serous cavities are not affected.

We have found that intravenous injection of thiourea causes an increase in blood pressure in the anæsthetized rat, but it is unlikely that this is related to the toxic effect as the dose required is comparatively large.

It is well known that rats poisoned with large doses of iodide show pleural effusion. In view of the chemical affinity of thiourea for the halogens, the possible relation between these two phenomena and the nature of the underlying dietary deficiency are being investigated.

F. W. Landgrebe.
(Beit Memorial Fellow.)
T. N. Morgan.

Department of Materia Medica,
University of Aberdeen.
Aug. 27.

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Seasonal Cycle and Inversion Frequency in Populations

The fact that the biological environment may determine the frequency of chromosome-changes in populations was first emphasized by Dubinin, Sokolov and Tiniakov[1], while Dobzhansky[2] first discovered the effect of selection on inversions, and the relation between changes of inversion frequency and seasonal cycles (in *Drosophila pseudoobscura*).

Our earlier work[1] on *D. funebris* showed that the proportion of flies heterozygous for different inversions varied seasonally from 75·7 per cent in December to 108·0 per cent in August, when the population was most numerous. Later work has confirmed this important fact and at the same time given us new results.

Table 1 shows the percentage of heterozygotes for inversion II–1 in every month of the seasonal cycle for three Moscow populations. Beginning with the low spring populations and ending with the high ones of summer and autumn, a marked increase in inversion frequency is seen, ranging from nearly fourfold in population III to nearly twenty-eightfold in population I.

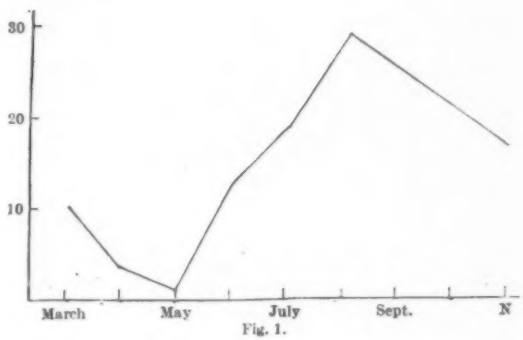

Fig. 1.

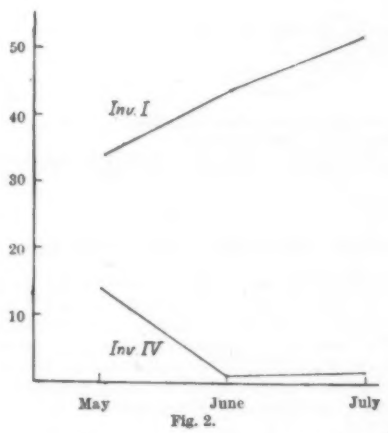

Fig. 2.

Fig. 1 illustrates the annual cycle of inversion frequency in population I.

It would be interesting to compare the behaviour of different inversions during the entire annual cycle, but there are not yet sufficient data. However, inversions II–I and IV–1 from population II show opposite trends during the period of rapid population increase from May to July (Table 2; Fig. 2).

Table 1. Percentage of heterozygotes for inversion II-1 during the seasonal cycle in *Drosophila funebris*, in Moscow, 1944–45.

Population	March	April	May	June	July	August	September	November	Average	Number of specimens
I. Hippodrome	10·1	3·4	1·1	12·5	18·8	29·5	—	17·1	12·9	1045
II. University Botanical Garden	—	—	33·7	44·0	52·0	57·6	53·2	—	45·88	501
III. Cloukh Street	13·5	27·7	—	—	43·1	41·9	50·8	—	19·79	869

TABLE 2. SEASONAL CHANGES IN PERCENTAGE OF HETEROZYGOTES FOR TWO DIFFERENT INVERSIONS IN POPULATION II (BOTANICAL GARDEN).

Inversion	May	June	July
II-1.	33·7	44·0	52·2
IV-1.	14·0	1·2	1·6

In future investigations we intend to ascertain the behaviour of all the principal inversions during the seasonal cycle.

Elsewhere[2] we have shown the marked difference in inversion frequency between urban and rural populations in *D. funebris*. It is of great interest to find that no significant seasonal changes in inversion frequencies occur in the rural populations studied by us at Kropotovo, 115 km. south-east of Moscow (Table 3).

TABLE 3. SEASONAL CHANGES IN PERCENTAGE OF HETEROZYGOTES FOR THREE INVERSIONS (II.1, II.2, IV.1) IN A RURAL POPULATION (KROPOTOVO).

	May	June–July	August	September	October	Average
%	3·4	0·1	1·7	0·8	1·7	1·26
Number examined	29	234	530	255	238	1286

The fact that urban populations of *D. funebris* exhibit seasonal cycles of inversion frequency, while rural populations do not, demonstrates the existence of one of the genetic reactions to environment which have led to the evolutionary stabilization of genetically divergent urban and rural races of this species.

The above facts not merely demonstrate that natural selection operates to modify the genetic structure of wild populations in relation to environment and to annual reproductive cycle, but also (contrary to the frequently expressed view that evolution is an extremely slow process) that it operates with great rapidity.

N. P. DUBININ.
G. G. TINIAKOV.

Academy of Sciences of the U.S.S.R.,
Institute of Cytology,
Ulitsa Obocha 6,
Moscow.

[1] Dubinin, Sokolov and Tiniakov, *Biol. Zhurn.*, **6**, 1007 (1937).
[2] Dobzhansky, *Genet.*, **28**, 162 (1943).
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Wind Measurements at 30 Km.

AN opportunity has recently occurred of making a series of measurements of the velocity and direction of the wind at a height of 30 km. Previous determinations of the wind at great heights have generally consisted of a few individual observations; but in the present instance an extended series of measurements has shown a striking annual variation of the wind in this region.

The measurements were made by following with theodolites the drift of smoke puffs produced by the bursting of smoke shells which were fired upwards from a high-velocity gun in south-east England. Thirty-five determinations were carried out at fairly regular intervals between February 1944 and May 1945.

The results show clearly that during summer the wind at a height of 30 km. is mainly easterly, whereas during winter it has a strong westerly component. The change-over takes place about April and October. In summer the direction varies between about north-east and south-east, and in winter between about south-west and north-west. Over the period covered by the observations, the mean velocity in summer was about 12 metres per second and in winter 37 metres per second. The greatest velocity observed was 66 metres per second from a direction 285° (true).

This annual variation in the direction of the wind at this height confirms the deduction made by the late Dr. F. J. W. Whipple from a study of the audibility of explosions at a distance.

A full description of the recent observations will be published shortly in a paper now being prepared by Flight-Lieutenant R. J. Murgatroyd, the meteorological officer associated with the investigation.

N. K. JOHNSON.

Meteorological Office,
Air Ministry. Nov. 21.

Flow Through Very Small Channels

A 'NEON' tube containing helium shows a characteristic ivory-coloured and rather shining positive column. With a trace of air the column assumes a matt appearance of approximately the same colour, while the effect of water vapour is to change it to rose-pink.

Normally a leaky tube shows the matt colour, but occasionally under very humid conditions and with very fine leaks the colour changes to rose. I cannot affirm that this is due to water alone, and not to a mixture of air and water, but as a bigger 'leak' under the same atmospheric conditions gives the 'air' colour, it seems that at least a larger proportion of water gets in through the finer channels.

Incidentally, it has been our custom to fill up glass 'pinch' funnels with Faraday wax, to guard against fine 'wire leaks'; and of course, where possible, glass tubes being sealed off under vacuum should have the hot glass well twisted in order to squeeze up the fine air line which sometimes occurs in the 'pip'.

O. P. SCARFF.

Longlamps, Ltd.,
24 Marshalsea Road,
London, S.E.1.

ALTHOUGH Mr. Scarff's observations with a helium discharge tube do not provide any quantitative basis of comparison, they are at least in qualitative agreement with our results[1], inasmuch as "very fine leaks" apparently showed a rose-pink discharge characteristic of water-vapour, while larger leaks allowed air to enter the tube. On the basis of our results it is easy to show that air, as distinct from water-vapour, will begin to leak into an evacuated tube when the width of the channel through which the leak occurs is greater than about 2×10^{-4} cm., that is, when the pressure due to the surface tension of the water falls to about one atmosphere.

We conclude that the "very fine leaks" in Mr. Scarff's observations must be of the order of 2×10^{-4} cm. in width, when one would expect a mixture of air and water-vapour to leak into the tube. With wider channels the amount of air leaking into the tube would, of course, rapidly increase. This agrees with Mr. Scarff's remarks that "a larger proportion of water gets in through the finer channels".

J. REEKIE.

Department of Physics,
The University, St. Andrews.

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RED, BROWN AND GREEN PIGMENTS IN LEGUMINOUS ROOT NODULES

By Prof. ARTTURI I. VIRTANEN and T. LAINE
Biochemical Institute, Helsinki

In addition to the red pigment, hæmoglobin, we have always found in leguminous root nodules a brown pigment. This is methæmoglobin with trivalent iron[1]. The simplest way of demonstrating its presence is to add sodium fluoride to the water extract of crushed nodules, whereby the characteristic absorption maximum of fluor-methæmoglobin at 610 mμ becomes visible. The equilibrium: hæmoglobin ⇄ methæmoglobin in the root nodules depends decisively on the intensity of light and on the stage of growth of the plants. The root nodules of vigorously growing legumes are red on bright days, the amount of hæmoglobin being high in comparison to that of methæmoglobin. During cloudy days the brown colour deepens in the nodules as the balance is shifted to methæmoglobin. If soybean is kept in complete darkness for two to three days, the colour of the nodules changes to brown. After a longer stay in the dark the colour turns green. In the pea the green colour is formed in a noticeably shorter time than in soybean[2].

When the growth of the plants is normally retarded after the end of flowering, the colour of the nodules undergoes a change similar to that of the young plants when lacking light. Finally, the nodules are even thereby turned green. The green nodules fix no more nitrogen, and the green pigment can no longer be transformed into hæmoglobin or methæmoglobin.

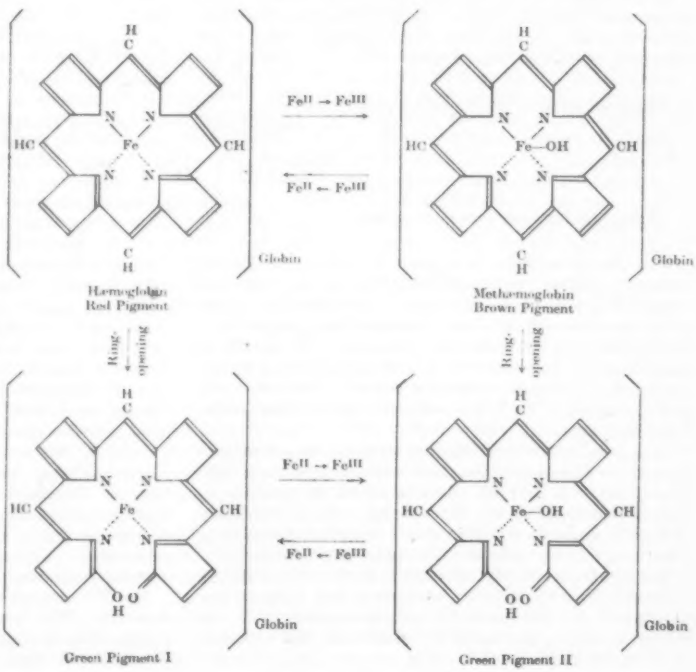
It is a general rule that the transformation of hæmoglobin into the green pigment denotes the cessation of nitrogen fixation. The root nodules formed by bacterial strains with a poor nitrogen-fixing ability often contain even at a young stage green pigment together with the red one. If the growing conditions are unfavourable, even the root nodules formed by very effective bacterial strains are partly turned green while still at a young stage. On the same roots both red and green nodules are then found side by side. Some perennial legumes such as the Siberian pea-tree (*Caragana arborescens*) have many oblong root nodules consisting of successive round nodules like pearls in a string. Only the youngest part of the nodule at the farther end is red, the rest being greenish or brownish in colour.

The brown pigment is methæmoglobin, as was mentioned above. This seems to be denatured with relative ease, and therefore also hæmatin as well as methæmoglobin is found in the brown nodules. When the brown nodules are crushed in water, the suspension obtained centrifuged and filtered through a bacterial filter, a brown slimy layer remains on the filter, which gives no characterizable spectrum when dissolved in dilute alkali solution, but after addition of sodium hydrosulphite gives absorption maxima characteristic of hæmochromogen (strong at 559 mμ and weaker at about 530 mμ).

The green pigment can be isolated from the nodules in the same way as the red and the brown pigments. On addition of ammonium sulphate, it is precipitated in approximately the same concentrations. The substance is a chromoprotein and contains iron in an undissociated form. The green pigment does not give the absorption bands of hæmoglobin. By the action of dilute hydrochloric acid in the presence of oxygen the iron is split off from the green pigment.

The hæmoglobin of the root nodules—as well as that of blood—is converted into the green pigment by ascorbic acid at about *p*H 7·5, when air is passed through the solution. This green pigment splits off iron when treated with dilute hydrochloric acid and its properties are also similar in other respects to those of the green pigment of the nodules. On the basis of our observations so far, the green pigment belongs to the precursors of the bile pigments and resembles in the first place the choleglobin of R. Lemberg[3].

We conclude that the green pigment contains divalent iron, since iron is split off from it by dilute hydrochloric acid only in the presence of oxygen. Carbon monoxide inhibits the reaction. However, in certain circumstances we have succeeded in splitting off some iron also in an atmosphere of carbon monoxide, which indicates that even the presence of trivalent iron in the green pigment



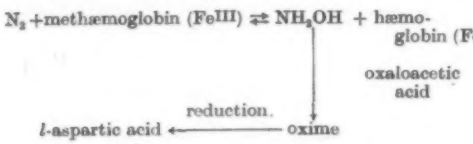
is possible. Barkan[4] has noted that from haemoglobin of blood both 'pseudohæmoglobin' (ferrous iron) and 'met-pseudohæmoglobin' (ferric iron) are formed.

As the formation of green pigment from the hæmoglobin of blood occurs, according to Lemberg, through the breaking of a porphyrin ring caused by simultaneous oxidation-reduction reactions, it can be assumed that the conversion of the hæmoglobin of the root nodules into the green pigment proceeds in the same way. Accordingly, the relation of the green and the brown pigment to hæmoglobin can be indicated by the scheme shown above (the side chains omitted)[1].

Along which of these lines the formation of green pigment proceeds, or whether it takes place in both ways, remains still to be discovered.

Oxaloacetic acid has an effective influence on the equilibrium: hæmoglobin ⇄ methæmoglobin. Methæmoglobin is reduced to hæmoglobin by the action of oxaloacetic acid. If the brown root nodules are put into a very dilute solution of neutralized oxaloacetic acid, they begin to turn noticeably red in a few hours, the balance going over to hæmoglobin. The changes in the colour of the nodules reported at the beginning of this communication depend on the intensity of light, and also follow to a surprising extent the variations of the oxaloacetic acid content of the plant juice. On bright days the oxaloacetic acid content of the plant juice is at its highest; during cloudy periods it falls sharply and after forty-eight hours in total darkness disappears completely. After the end of flowering, oxaloacetic acid is no longer found in plants growing in the light. Accordingly, oxaloacetic acid can be considered, as has been previously suggested by us, a decisively important factor in nitrogen fixation by leguminous root nodules.

On the basis of the observations so far made, it can be assumed that nitrogen fixation is connected with valency changes in the hæmoglobin iron, for example, in the following way[5]:



The above scheme is a gross formula and by no means signifies that hydroxylamine is directly formed from molecular nitrogen. The reaction occurs evidently through various intermediate stages as a result of oxidation-reduction processes. It should be mentioned in this connexion that Letsche[6] has noted that the reaction between hydroxylamine and oxyhæmoglobin leads to methæmoglobin and molecular nitrogen.

Our results concerning the occurrence and significance of hæmoglobin, methæmoglobin, and the green pigment in root nodules make it possible to estimate approximately the nitrogen-fixing efficiency of root nodules in cultivated soil simply by watching the colour of the nodules on the plane of intersection. If the colour is red, the activity is high; if the colour is brown, the activity is lower and the balance lies too much on the side of methæmoglobin; if the colour is green, the activity is nil and the nitrogen fixation irrevocably at an end.

I suggest the names 'leghæmoglobin' and 'leg-methæmoglobin' for the hæmoglobin and methæmoglobin of the root nodules.

[1] Virtanen and Laine, *Suomen Kemistilehti*, B, **18**, 36 (1945).
[2] Virtanen, *Nature*, **155**, 747 (1945).
[3] Lemberg, *Biochem. J.*, **29**, 1322 (1935); Lemberg, Legge and Lockwood, *Nature*, **142**, 148 (1938).
[4] Barkan and Schales, *Z. physiol. Chem.*, **248**, 96 (1937).
[5] Virtanen and Laine, *Suomen Kemistilehti*, B, **18**, 38 (1945).
[6] Letsche, *Z. physiol. Chem.*, **80**, 412 (1912); Müller, "Oppenheimers Handbuch der Biochemie", **1**, 456 (1924).

THE LISTER INSTITUTE OF PREVENTIVE MEDICINE

THE 1945 report of the Governing Body of the Lister Institute of Preventive Medicine records a wide range of researches of which its director and staff may rightly be proud. The continued study of *Vi* bacteriophage has added one further *Vi*-phage type of the typhoid bacillus to the list of new types or subtypes identified in the British Isles, and there is evidence that unknown phage-types of typhoid and paratyphoid B bacilli are being introduced from abroad. The typing of *Bact. typhi-murium*, which is one of the commonest causes of food-poisoning in Great Britain and other countries, is proceeding and a scheme has been prepared for the routine application of the *Vi* test to future cases of typhoid fever, with the object of keeping a check, so far as this is possible, on persons who are likely to become persistent carriers of typhoid bacilli.

Immunological work includes studies of vaccinia virus and of extracts of *Bact. shigæ* in relation to dysentery prophylaxis. The important work previously done upon immunization against the gas gangrene organisms and upon chemical and other aspects of this serious infection continues and expands. Not least important is the work being done on the production of a whooping cough vaccine, for the need for this is great. Important also is the continuation of previous outstanding work upon trichomoniasis of cattle, which is at once a good example of co-operation between biologists, medical men and veterinarians and also of valuable work in aid of the national food supplies.

Biochemical studies include work on specific blood-group substances derived from hog gastric mucin and ovarian cyst fluids, on the analysis of amino-acids and on those interesting antibacterial substances obtained from soil bacteria, gramicidin and gramicidin S (see *Nature*, **155**, 246; 1945). Studies of the combined antioacterial action of these two gramicidins and penicillin have shown that they do not synergize each other. Interesting studies are being made of plasma products (fibrinogen, prothrombin) and of materials prepared from them such as fibrin foam (see *Nature*, **155**, 279; 1945) which is being produced for clinical use. On the basis of experience gained in the study of freeze-drying, a large-scale plant has been erected by Imperial Chemical Industries at Manchester for the drying of penicillin, and the apparatus devised has been used for freeze-drying of human milk, vaccine lymph and human plasma products. Fœtal and maternal hæmoglobin and certain hormones are also being studied.

For its nutritional work the 'Lister' is deservedly famous. This report records further work on the potato, the nitrogenous food value of which definitely deteriorates when it is stored for months in a clamp.

No evidence has been found in favour of the view that there are more nitrogenous food elements in the potato skin, and a new protein has been discovered in potatoes. It has been found that rats kept upon a diet of potato without any other source of vitamin A can survive indefinitely without the skin lesions associated with vitamin A deficiency; on the other hand, severe gastric ulceration has been produced in rats deprived entirely of vitamin A. The non-protein nitrogen of potatoes, which cannot alone support growth, markedly supplements wheat gluten, and the proteins of dried yeast have been found to be much inferior in value to those of whole wheat, although a mixture of the two is better than whole wheat. A mixture of yeast protein and non-protein nitrogen is also better than yeast protein alone. The nitrogenous substances in domestic 'beef tea' had no growth-promoting value; but a mixture of them with those of white flour was much better than the proteins of white flour alone. Beef extract and yeast probably owe their supplementary value for cereal protein to their high content of the amino-acid lysine, in which cereal proteins are relatively deficient. Much valuable work has been done on the vitamin B complex in foodstuffs for the Royal Air Force, the Ministry of Food and the Medical Research Council. Other nutritional work includes studies of the biological estimation of vitamins, the effects of iodine deficiency upon human disease and on nicotinamide and its related compounds. The well-known studies of vitamin C done at the Lister Institute by members of the Medical Research Council's external staff continue.

It must be a source of satisfaction to the Institute that those members of its staff who were evacuated and given accommodation in other widely separated laboratories are now returning to London. The contacts made by these members of the staff during the war years must have benefited greatly both the Lister Institute and the various institutions in which these members of its staff were accommodated.

G. Lapage.

MICRO-ORGANISMS AND THEIR ENVIRONMENT

A SYMPOSIUM meeting of the Society for General Microbiology was held at Cambridge on July 5 and 6, 1945, the topic of the symposium being "The Effect of Environment on the Morphology and Activities of Micro-organisms". The symposium occupied two sessions (afternoon and morning), the third session being devoted to the reading of papers on a variety of topics; there were also a number of interesting demonstrations. The aim of the organizers in choosing the wide topic for the symposium had been to provide opportunity for contributions from the many disciplines of microbiology in general, in order to foster one of the main objects of the Society, namely, to promote the advancement of microbiology by providing a common meeting-ground for those working in all the various specialized branches. In the event, the papers submitted at the symposium were weighted on the side of biochemistry, and there were fewer papers of more biological character than had been hoped. Perhaps this distribution reflects the present emphasis of active work in Britain, or it may be that authors who could have contributed valuably from other angles were too diffident. Whatever may have been the cause of the actual distribution of papers in the symposium, the Society will no doubt draw the necessary conclusions from its first venture, and continue in its endeavours to help weld together the various branches of microbiology, when organizing future symposia. The other contributions, both papers and demonstrations, were effective in restoring the balance of this two-day meeting, making it more representative of general microbiology.

Below is given a brief summary of the topics discussed in the symposium. In her introductory remarks, the chairman, Dr. Marjory Stephenson, referred to the increasing study during the last fifteen years of the so-called adaptive enzymes of bacterial cells, which appeared when suitable substrates were present in the environment of the cell; to the changes in the enzymic properties of cells during their life-period; and to physical factors of the environment which could affect the enzyme make-up of the cells. The microbial cell was in part a continually changing system of enzymes modified by a changing environment, in contrast to the animal cell where a relatively constant system of enzymes was maintained by a close control of the cell's environment.

The different sets of conditions which might affect bacterial growth, the formation of specific antigens (in particular, toxins), and the effectiveness of antigens as stimulants of antibody formation (their antigenicity) were indicated by W. E. van Heyningen. Miss M. Barr discussed methods of determining the quality of toxoids as antigens, and indicated a rapid method by which this could be done, based on an evaluation of the relative affinity of different toxoids for antitoxin. Other factors influencing the antigenic efficiency of a toxoid (for example, presence of other substances, condition of the responding animal) were discussed. The two foregoing papers emphasized the many factors, both in the environment of the bacteria producing an antigen and in the environment in which the antigen was used, which could affect the formation and behaviour of the antigen.

There followed a group of papers on biochemical aspects: the effect of iron concentration on the fermentation of glucose by *Cl. welchii* (E. E. Bacon); the influence of enzymically hydrolysed hyaluronate on the formation of hyaluronidase by streptococci (H. J. Rogers); the metabolism of pantothenate by bacteria in growing cultures as compared with non-proliferating cell suspensions in simple media (H. McIlwain); the influence of the composition of the medium on the products of fermentation by *Clostridium acetobutylicum* Weizmann (H. Davis and Marjory Stephenson); the influence of Mg^{++} and K^{+} ions on the metabolic activities of certain bacteria (J. H. Quastel); the effect of the physico-chemical conditions during growth on the amino-acid catabolism of bacteria (E. F. Gale); the influence of the environment on the velocity of adaptation in the formation of tetrathionase by *Bact. paratyphosum B.* (R. Knox); the influence of temperature on the formation of tetrathionase in washed suspension of *Bact. paratyphosum B.* (M. R. Pollock).

Observations on the viability and infectivity for mice of suspensions of *Erysipelothrix rhusiopathiæ* as affected by various suspension media were discussed by G. Slavin and M. H. Maclay. The effects of various environmental factors on the colonial morphology of soil *Actinomycetes* were described by Dagny Erikson Oxford. This concluded the symposium, during which there was discussion on the contributions.

The following papers were also read: insect transmission of a plant virus complex, tobacco rosette (K. M. Smith); the rate of inactivation of vaccinia virus dried from the frozen state (D. McClean); iron organisms (E. G. Pringsheim); the life-cycle of sporing *Actinomycetes* (E. Klieneberger-Nobel); the site of proliferation of nitrifying bacteria in soils (H. Lees and J. H. Quastel); variation in symbiotic activity within a pure-line strain of clover nodule bacteria (P. S. Nutman and J. Kleczkowska).

The following demonstrations were exhibited in the Molteno Institute: warm-stage and cytological observations on the early development of the avian tubercle bacillus (E. M. Brieger, H. B. Fell and C. Robinow); avian malaria (Ann Bishop); plant viruses and virus diseases (K. M. Smith); cultures of Algæ and flagellates (E. G. Pringsheim); the soil perfusion unit (H. Lees and J. H. Quastel).

FORTHCOMING EVENTS

Saturday, January 5

ROYAL INSTITUTION (at 21 Albemarle Street, London, W.1), at 2.30 p.m.—Sir Robert Watson-Watt, F.R.S.: "Wireless" (Christmas Lectures adapted to a Juvenile Auditory, 5).

Monday, January 7

FARMERS' CLUB (at the Royal Empire Society, Craven Street, Strand, London, W.C.2), at 2.30 p.m.—Dr. S. J. Wright: "Mechanisation".

Tuesday, January 8

ROYAL INSTITUTION (at 21 Albemarle Street, London, W.1), at 2.30 p.m.—Sir Robert Watson-Watt, F.R.S.: "Wireless" (Christmas Lectures adapted to a Juvenile Auditory, 6).

ILLUMINATING ENGINEERING SOCIETY (at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1), at 6 p.m.—Discussion on "The B.S.I. Specification for Street Lighting" (to be introduced by Dr. J. W. T. Walsh).

Wednesday, January 9

SOCIETY OF CHEMICAL INDUSTRY (joint meeting of the MICROBIOLOGICAL PANEL OF THE FOOD GROUP with the SOCIETY FOR APPLIED BACTERIOLOGY, at the Chemical Society, Burlington House, Piccadilly, London, W.1), at 2.15 p.m.—Dr. A. T. R. Mattick and Miss E. R. Hiscox: "Some Observations on Heat-Resistance of Micro-organisms"; Dr. C. L. Hannay: "Some Problems in the Bacteriology of Rivers"; Mr. A. J. Musgrave: "Mould Growth on Leather".

ROYAL SOCIETY OF ARTS (at John Adam Street, Adelphi, London, W.C.2), at 2.30 p.m.—Commander H. P. Mead: "Flags" (Dr. Mann Juvenile Lectures, 2).

INSTITUTE OF PETROLEUM (at 26 Portland Place, London, W.1), at 5.30 p.m.—Messrs. S. F. Birch, P. Docksey and J. H. Dove: "The Production of *Iso*-Hexane and *Iso*-Heptane by Super-Fractionation".

INSTITUTION OF ELECTRICAL ENGINEERS, TRANSMISSION SECTION (at Savoy Place, Victoria Embankment, London, W.C.2), at 5.30 p.m.—Mr. P. J. Ryle: "Steel Tower Economics".

IRON AND STEEL INSTITUTE (joint meeting with the EBBW VALE METALLURGICAL SOCIETY, at the Rational Hall, Ebbw Vale), at 6.45 p.m.—Dr. J. H. Chesters: "The Limiting Factor in Open-Hearth Design".

SOCIETY FOR VISITING SCIENTISTS (at 5 Old Burlington Street, London, W.1), at 7.30 p.m.—Discussion on "Science in Canada and South Africa" (Speakers: Dr. E. W. van Heyningen, Major E. Boden, Dr. J. G. Malloch and Dr. R. Y. Stanier).

Thursday, January 10

SOCIETY OF CHEMICAL INDUSTRY, PLASTICS GROUP (joint meeting with the FARADAY SOCIETY, at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1), at 2.30 p.m.—Dr. G. B. B. M. Sutherland: "The Infra-Red Examination of Plastics".

LINNEAN SOCIETY (at Burlington House, Piccadilly, London, W.1), at 5 p.m.—Scientific Papers and Exhibits.

INSTITUTION OF ELECTRICAL ENGINEERS, INSTALLATIONS SECTION (at Savoy Place, Victoria Embankment, London, W.C.2), at 5.30 p.m.—Mr. W. R. Watson: "The Control of Electrical Installation Work".

WOMEN'S ENGINEERING SOCIETY, MANCHESTER BRANCH (at the Engineers' Club, Albert Square, Manchester), at 6.30 p.m.—Mr. G. W. G. Canter: "Ships' Engines".

PHARMACEUTICAL SOCIETY (at 17 Bloomsbury Square, London, W.C.1), at 7 p.m.—Mr. R. R. Bennett: "The British Pharmacopœia".

Friday, January 11

ROYAL ASTRONOMICAL SOCIETY (at Burlington House, Piccadilly, London, W.1), at 5 p.m.—Additional meeting to meet the French astronomers, Dr. D. Chalonge, Dr. A. Couder, Prof. A. Danjon, Prof. J. Dufay and Dr. B. Lyot.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS (in the Lecture Theatre of the Mining Institute, Newcastle-upon-Tyne), at 6 p.m.—Mr. J. W. Stephenson: "Science and Craftsmanship in the Engineer and Shipbuilding Industries".

BRITISH ASSOCIATION OF CHEMISTS, ST. HELENS SECTION (at the Y.M.C.A. Buildings, St. Helens), at 7.30 p.m.—Mr. F. Mould: "Hormones".

Saturday, January 12

ASSOCIATION OF BRITISH ZOOLOGISTS (at the Zoological Society, London, Regent's Park, London, N.W.8), at 10 a.m.—Eleventh Annual Meeting.

INSTITUTION OF MECHANICAL ENGINEERS, GRADUATES' SECTION (at Storey's Gate, St. James's Park, London, S.W.1), at 3.30 p.m.—Mr. S. Sarwal: "Fuel Injection System on Diesel Engines".

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

LECTURER IN PHYSICAL CHEMISTRY, and a LECTURER IN MATHEMATICS—The Registrar, College of Technology, Manchester 1 (January 14).

ASSISTANT LECTURER IN CIVIL ENGINEERING—The Registrar, The University, Manchester 13 (January 14).

CHIEF CHEMIST, Grade S, a JUNIOR TECHNICAL ENGINEER, Grade 10, a COMBUSTION ENGINEER, Grade 8a, and ASSISTANT PLANNING ENGINEERS (3), Grade 9a, to the Borough of Fulham Electricity Department—The Town Clerk, Town Hall, Fulham, London, S.W.6 (January 14).

ELECTRICAL ENGINEER AND MANAGER to the County Borough of Wigan—The Town Clerk, Municipal Buildings, Library Street, Wigan (January 14).

SENIOR DIETITIANS (Technical Officers, women) by the Ministry of Food, Food Advice Division—The Ministry of Labour and National Service, Appointments Department, Technical and Scientific Register, Room 572, York House, Kingsway, London, W.C.2, quoting F.4631.A (January 15).

CHIEF CHEMIST—The Water Engineer and Manager, Spon House, 21 Allesley Old Road, Coventry (January 16).

ASSISTANT BOROUGH ANALYST AND DEPUTY GAS EXAMINER—The Town Clerk, Civic Centre, Southampton, endorsed 'Assistant Borough Analyst' (January 17).

HEAD OF THE CHEMISTRY DEPARTMENT of the Municipal Technical College—The Chief Education Officer, Education Offices, Nelson Square, Bolton (January 17).

ASSISTANT MASTER to teach PHYSICS up to University scholarship standard in the City of London School—The Town Clerk, 55-61 Moorgate, London, E.C.2 (January 18).

VACANCIES (2) on the staff of the Water Pollution Research Laboratory, Watford, mainly for research on methods of treatment of water, sewage and trade waste waters (Ref. No. F.5087.A), and one VACANCY on the staff of the Chemical Research Laboratory, Teddington, for research on the methods of separation of tar components, including distillation (Ref. No. F.5216.A)—The Ministry of Labour and National Service, Appointments Department, Technical and Scientific Register, Room 572, York House, Kingsway, London, W.C.2, quoting the appropriate Ref. No. (January 18).

ASSISTANT LECTURER IN ZOOLOGY—The Registrar, University College of Wales, Aberystwyth (January 19).

BIOLOGISTS (honours graduates in Botany with subsidiary qualifications in Zoology and/or Bacteriology) at (i) the North Eastern Laboratory at Wakefield, (ii) the West Midland Laboratory at Birmingham, (iii) the South Western Laboratory at Bristol, (iv) the North Western Laboratory at Preston (Ref. No. F.5063.A); CHEMISTS (with honours degree in Chemistry, experience of micro-analysis and the use of physico-analytical instruments) at (i) the North Eastern Laboratory at Wakefield (Ref. No. F. 5387.A), and (ii) the South Western Laboratory at Bristol (Ref. No. 5388.A)—The Ministry of Labour and National Service, Appointments Department, Technical and Scientific Register, Room 572, York House, Kingsway, London, W.C.2, quoting the appropriate Ref. No. (January 19).

BOROUGH WATER ENGINEER—The Town Clerk, Town Hall, Watford, Herts., endorsed 'Water Engineer' (January 21).

ENGINEERING ASSISTANTS, CIVIL (senior and junior), by the Crown Agents for the Colonies for their Engineering Designs Department—The Ministry of Labour and National Service, Technical and Scientific Register, Room 572, York House, Kingsway, London, W.C.2, quoting E.2135.A (January 24).

GENERAL ENGINEERING ASSISTANT in the Borough Engineer's Department—The Borough Engineer, Town Hall, Burton-upon-Trent, endorsed 'General Engineering Assistant' (January 25).

PROFESSOR OF ENGINEERING in the University of Melbourne—The Secretary, Universities Bureau of the British Empire, c/o University College, Gower Street, London, W.C.1 (in Melbourne, February 15).

ASSISTANT in the Registrar's Office (university degree and secretarial training essential)—The Secretary, Bedford College for Women, Regent's Park, London, N.W.1.

ASSISTANT ENGINEERS, Grade B (2), ASSISTANT ENGINEERS, Grade C, an ASSISTANT ENGINEER FOR WASTE, Grade B(2), and MECHANICAL ENGINEERING DRAUGHTSMEN, Class II, Class I(2), Class I(1)—The Clerk to the Metropolitan Water Board, New River Head, Rosebery Avenue, London, E.C.1.

DEPUTY BOROUGH ELECTRICAL ENGINEER AND MANAGER—The Electrical Engineer, Wallasey Road, Wallasey.

LECTURER (man) FOR TECHNICAL ASPECTS OF VISUAL EDUCATION—The Registrar, University College, Exeter.

CHEMIST (male) in the Mineral Resources Department—The Establishment Officer, Imperial Institute, South Kensington, London, S.W.7.

PROFESSOR OF SOCIAL ANTHROPOLOGY in the Natal University College, Durban—The Secretary, Universities Bureau of the British Empire, c/o University College, Gower Street, London, W.C.1.